

Using Computer Simulation to Plan and Design Traditional Dong Towns & Villages in Mountainous Areas of Tongdao, Hunan, China

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Abstract

This paper details the use and outcomes of an automated computer planning and design simulation program, using Dong towns & villages in Tongdao, Hunan as the basis for research. The planning and design program simulates the traditional “site selection” and “expansion” processes for these towns and villages, automatically taking into account the cultural customs, community structures, and spatial characteristics of the Dong people. Encouragingly, the simulation program has successfully reproduced the traditional layout and expansion manner of existing Dong towns & villages. It is considered that the use of this program will help to protect traditions and landscapes as China continues to undergo rural-urbanization.

1 Introduction

The New Rural Construction is accelerating in China (Guo, J. Z. and Li, K. 2006). Therefore, how to protect the towns & villages’ traditional cultures and rural landscapes has become a hot topic (Feng, J. C. 2013), in the face of large-scale relocation and resettlement of towns & villages. It is difficult for traditional planning and architectural design institutes to systematically research the traditional cultures, architectural forms and geographic information of varied towns & villages, due to the short design cycle and limited manpower (Figure 1).



Figure 1: Damage to the rural landscape by simple and crude planning and design. Image Source: <https://www.worldphoto.org/zh/node/1549>

This paper introduces a new rural planning and design program that can computer simulate the traditional “site selection” and “expansion” process of small towns & villages in China (Figure 2). We have used the Dong nationality (Figure 3) in Tongdao, Hunan, as the research basis. The simulation is structured around the traditional cultures, spatial patterns and geographical environment information of Dong towns & villages. The program can be used to assist in the protection of rural cultures and landscapes in light of rapid urbanization of the rural landscape.

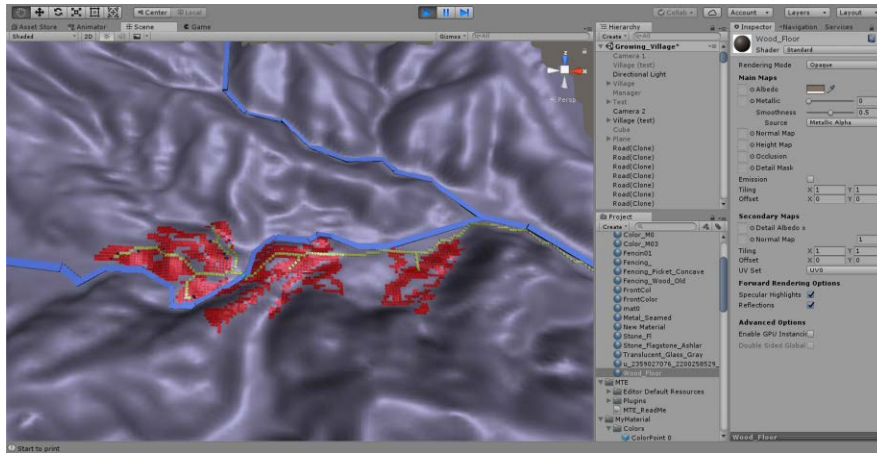


Figure 2: A town pattern created by the simulation program (with the main menu).



Figure 3: Representative examples of Dong towns. Image Source: <https://www.gettyimages.co.uk/detail/photo/dong-minority-girl-royalty-free-image/168505385>

Tongdao is located in the southwest of Hunan province, China, bordering Guangxi and Guizhou province, and is one of the major settlements of the Dong people. Located in the mountains and physically isolated from major centers of population, Dong towns & villages are less influenced by Han culture and customs. As a result, the traditional culture and ethnic characteristics of the Dong people are well preserved through the distinctive built character and design of their settlements. The Dong nationality is the most "architectural" nation among the ethnic minorities in China (Liu, S. 2008).

The Dong people have a unique social organization and town structure. The traditional Dong society is mainly composed from the bottom up of families, ethnic groups, clans, villages, towns and grand towns (Figure 4). Towns in the same area comply with the same local law “Kuan” to form an alliance. The layout of the Dong towns & villages is significantly affected by this social structure, where clan inhabitants form a clustered layout around a traditional drum tower (further detailed in Section 1.4).

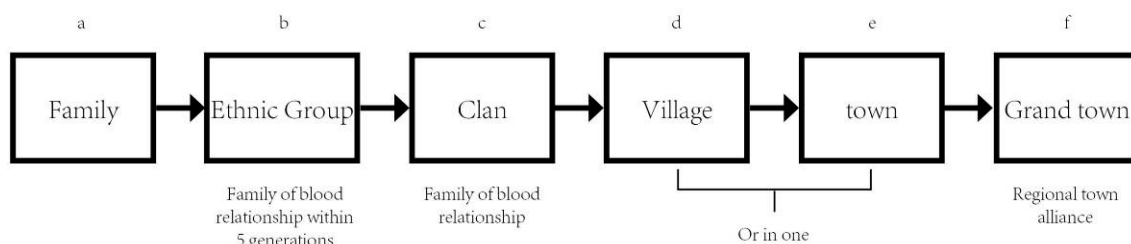


Figure 4: Social structure of Dong nationality. Image Source: Cai, L. 2013 (redrawn)

The cultural characteristics of the Dong towns & villages are unique, well-kept, and clear in organizational structure, which are characteristics that are conducive to being input into a computer simulation.

2 Background

The use of computer simulations in relation to human settlements has become more common in recent years. For example, Parish and Müller proposed a user guided city-generation based on an L-system (2001). Weber et al. developed an interactive geometric simulation of 4D cities (2009). Vanegas et al. presented an interactive dynamic system for the design of urban spaces using geometrical and behavioral modeling (2009). Emilien discussed village growth simulations on arbitrary terrains (2012). Beneš et al. demonstrated procedural modelling of urban road networks (2012). Batty simulated the urban form of a randomly established tree structure (2009). Leach established the concept of "group intelligence" to generate swarm cities (2009). PanahiKazemi and Rossi applied computational strategies for intervention in informal settlements (2014).

The pattern of human settlements are most often related to geographical conditions, nationalities, and cultures. Therefore, a simulation could be meaningful only if it captures the specific local geographical, ethnic characteristics, and cultural customs. By studying the site selection, growth and expansion of Dong towns & villages, the simulation program tries to extract the "genes" of the traditional Dong settlements and simulate it in a way that meets the traditional context and is compatible with the local environment.

3 Simulation Procedures

1.1 Overview

The author conducted a field survey of 13 Dong towns & villages in Tongdao (Figure 5, Table 1). Among them, there are 4 mountain-type towns and 9 riverside-type towns.

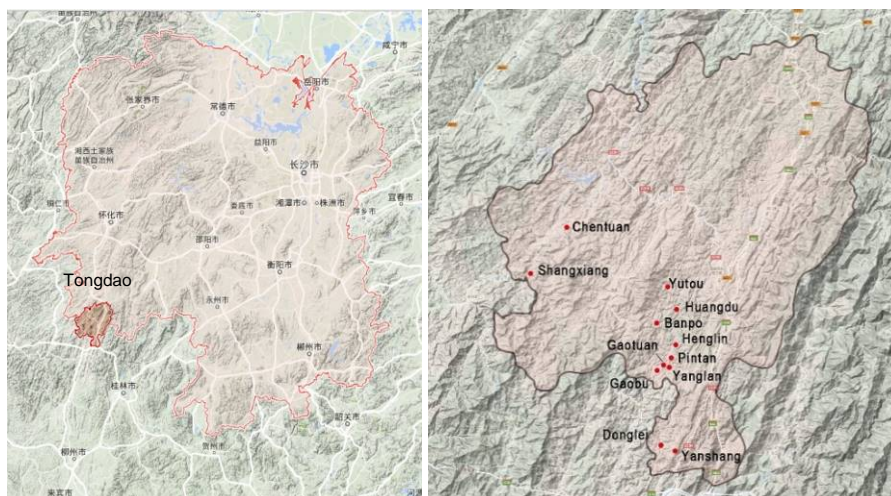


Figure 5: Location of Tongdao in Hunan province (left), distribution of the surveyed towns in Tongdao (right). Image Source: Google map (redrawn)

Table 1: Surveyed villages sorted by type

Mountain-type				Riverside-type				
Yutou	Yanshan	Banpo	Gaobu	Huangdu	Pintan	Gaotuan	Shangxiang	Donglei
				Hengling	Yanglan	Zhongbu	Chentuan	

A comprehensive statistical analysis of the Dong towns in Table 1 is conducted through related paper reading, field investigation, aerial photography, three-dimensional model reconstruction and CAD drawing. The results of this analysis are then used to establish the towns & villages' site selection, growth rule formulation and parameter settings, which can then be input into the computer simulation.

The main contents of the simulation program can be divided into four parts: environmental analysis; site selection & assessment; selection of the first drum tower site; and selection of new drum tower sites and settlement expansion.

1.2 Environmental analysis

1.2.1 Classification

Farmland is an important factor that affects the layout of towns & villages. Farmland located in flat valleys close to a river is a basic principle that forms the foundation of the layout of Dong towns & villages. By observing the layout of farmland and buildings in different types of towns, the author divides the Dong towns & villages into two terrain types: the mountain-type and the riverside-type (Figure 6). In mountain-type towns & villages, all flat valleys close to the river are primarily used as farmland, and housing will traditionally be located on gentle slopes at the foot of the mountain. Riverside-type towns & villages are usually located in wide, flat areas nearby a river. Having abundant flat land for farmland, housing will usually be located in the middle of the plains. Due to flood control considerations, housing is often kept at a distance from the river, and will form a clustered pattern surrounded by farmland.



Figure 6: Mountain-type town Yutou (left) and riverside-type town Gaobu (right). Image Source: self-photographed and self-drawn

Therefore, the simulation program will first perform a slope analysis of the terrain to determine its type and will then use different slope and altitude parameters to perform an environmental assessment according to the different terrain types.

1.2.2 Analysis

The Dong people live on rice farming and plantation forestry (Cai 2013), therefore, the basic principle of site selection is being close to a mountain or river. From the cultural point of view, the Dong people inherited the remains of the ancient Baiyue culture, namely the tradition of "being in the valley, among bamboos," and "mountain and water". This is because rice cultivation requires a source of water, and the mountain can provide wood for the construction of houses, while providing space for plantation forests and terraced fields (Cai 2013).

Mountain and water are the most important influence factors for Dong towns & villages. The program simulates the influence of mountains and water resources on the site by analyzing the hydrophilicity, elevation, slope, and geographic dominance of the given terrain (Figure 7).

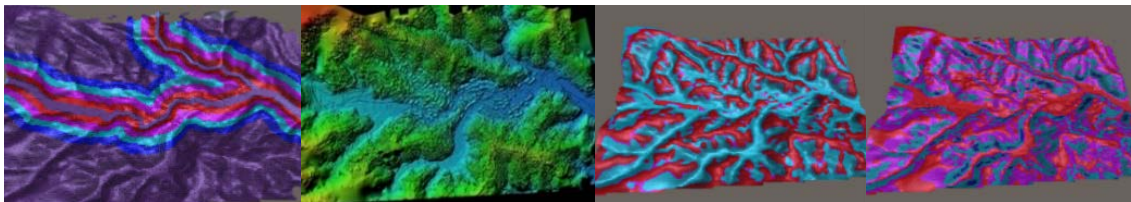


Figure 7: Yutou town's hydrophilicity, elevation, geographic dominance and slope analysis

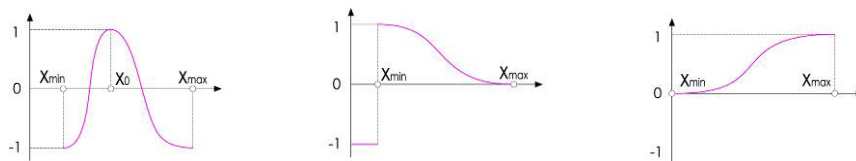


Figure 8: From left to right, function of slope & elevation, hydrophilicity, geographic dominance

The results of the environmental analysis are reflected in a scoring function at each point ("P") of the terrain model. Each point has a score range of -1 to 1. Negative numbers indicate sites undesirable for selection, and positive numbers indicate sites ideal to be selected. There are different functions for different environmental criteria to obtain the corresponding scores (Figure 8). x_{min} , x_0 , and x_{max} are parameters set according to different function. x_{min} , x_{max} represent the maximum and minimum values of an environmental factor. The x_0 value represents the ideal value. Finally, the program combines various criteria scores with different weight factors. From these results, we can choose the area ("G₀") that is geographically suitable for the location of the village or town (Figure 4). However, the area obtained at this stage is not the final site selection area, but rather a collection of all possible site selection areas of the terrain model (Figure 9 and Figure 11). In the next step, we need to determine the first village (Figure 4d) that forms part of the town. The area that best suits the Dong culture will be selected from area G₀.

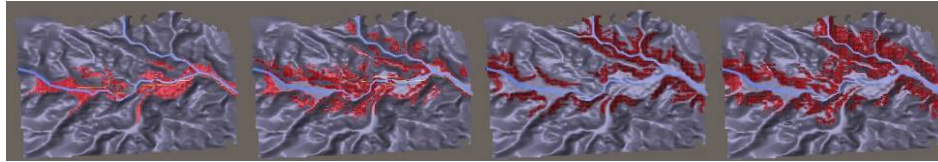


Figure 9: Influence of slope on site selection. x_0 value: 0, 15, 30, 45 degrees (from left to right)

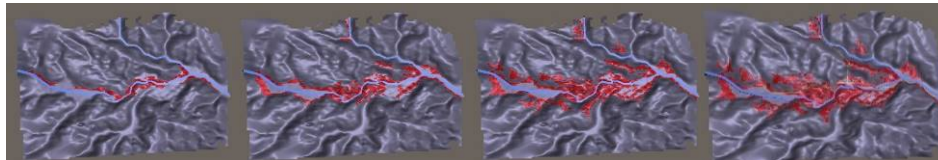


Figure 10: Influence of hydrophilicity on site selection. x_{min} value: 40, 100, 160, 200 meters (from left to right)

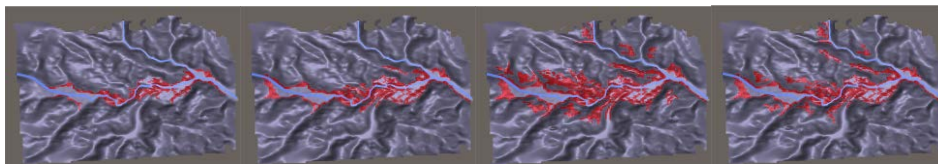


Figure 11: Influence of elevation in site selection. x_0 value: 280, 400, 520, 760 meters (from left to right)

1.3 Site Evaluation

Environmental analysis is objective based on the influence of slope, hydrophilicity and elevation. However site evaluation will also require consideration of emotional and cultural factors. The site selection of Dong towns and villages follows the “Fengshui” concept similar to that of the Han nationality. Song identified (2016) that traditional settlements of the Dong people are mostly built with the characteristics of “sitting west, facing east, leeward to the sun, facing water and backing to the mountain”. As most Dong people live in mountainous areas, with constrained direct sunlight, and little airflow, facing east is conducive to receiving sunlight in the morning for the purpose of heating. Zhou mentions (2008) that ancient towns & villages in west Hunan are usually settled on the side of the mountain that is embraced by a river, which is the “lucky side” in the native “Fengshui” concept, while the opposite side is the “unlucky side”. Flood control is another important factor that influences site selection (Figure 12). Cai summarized (2013) that the ideal site of a town based on the “Fengshui” concept is with its back to the mountains, with “guarding” mountainous areas to the sides, facing a flat and wide plain, embraced by river, and that the downstream of the river should bend.

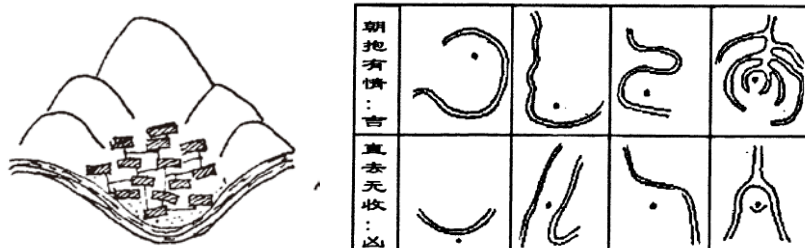


Figure 12: Ideal site selection (left), lucky (right upper) and unlucky (right lower) river side. Image

Source: Zhou, T. 2008

In summary, the best site location for the Dong people would be a town located on the south-east side of a mountain, facing a flat and wide plain, embraced by river. At the same time, a large enough site area is necessary for future development. Based on this logic, the program selected the area G_1 from G_0 as the first village site of the town (Figure 13).

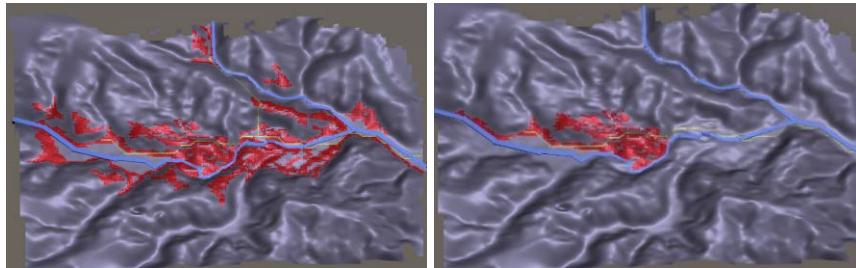


Figure 13: All possible site selection areas G_0 (left), and the first village site area G_1 (right)

1.4 Organizational Structure of Dong Villages and Towns, and Drum Tower Siting

Several clans (Figure 4c) cluster together around a drum tower to form a village (Figure 4d), and several villages will form a town (Figure 4e). This is the basic organizational structure (Figure 4) followed by the Dong people. Drum towers are a symbol of the political and cultural center of Dong towns & villages, and are an important meeting place, including for festivals and daily life of the Dong people. During times of war, drum towers are also important buildings for defense and transmission of information between nearby Dong villages. Drums placed on the tower would be knocked to summon clan members (Cai, L. 2013).

After the simulation program determines the suitable area for the first village, the next step is to locate a drum tower. Based on the core position of the drum tower, the most common location is at the center of the village. As a defense building, a drum tower needs to be situated in a position that can overlook the village. Therefore, riversides and main entrances are also common site selection locations. Among 32 drum towers the author visited (Table 2), there are 15 located in the village center, 13 located on the riverside, and 12 located at the village's main entrance, with a probability of approximately 4:3:3.

Table 2: Drum tower statistics

Type	Name of town	Name of drum tower	Location factor*	Distance to the nearest drum tower (m)	Number of houses attracted	Influence radius (m)
Mountain-type	Yutou	Longshi	ME	105	40	108
		Yashang	RS	105	52	83
		Lushen	C, RS	98	56	104
		Tianzhong	C	98	25	94
	Banpo	Zhaiqian	C, RS	108	55	155
		Banpo	C	108	57	137
Yanshang	Zhongxin	C	NA	35	126	

Riverside-type	Huangdu	Touzhai	ME	32	50	84	
		Weizhai	ME	32	52	77	
		Chongyang	ME, RS	54	47	103	
	Henglin	Zhaimen	ME	125	50	91	
		Hebian	RS	125	58	81	
	Pintan	Zhongxin	ME	NA	85	100	
	Yanglan	Zhongxin	C	59	40	80	
		Yanglan	RS	59	57	74	
	Gaotuan	Cuntou	ME, RS	75	26	62	
		Zhongxin	C	70	33	56	
		Cunwei	ME	70	24	48	
	Gaobu	Shangtun	ME, RS	119	67	88	
		Yangtian	C, RS	131	47	96	
		Longxin	C	95	84	74	
		Hebian	RS	95	77	102	
		Cunkou	ME	114	67	89	
		Yanzhai	C	114	43	87	
	Zhongbu	Zhongxin	C	100	64	103	
		Xinzhai	ME	100			
	Shangxiang	Shangxiang	C, RS	NA	79	104	
	Chentuan	Lao	C	101	75	118	
		Xin	C	101	68	127	
	Donglei	Lao	C	97	163	193	
		Zhaimen	C, RS	97	78	112	
		Hebian	RS	192	62	132	
	Averages				96	59	99

*ME: Main Entrance; RS: Riverside; C: Center

1.4.1 Siting the first Drum Tower

We can use the following steps to calculate the position of the first drum tower. 1) Calculate center of mass of G_0 area, to get point A (Figure 14a). Then find the nearest riverside location B from point A (Figure 14a). 2) Generate a path L (Galín et al. 2010) from A to the outside point of the village (predefined). The intersection point C between L and the G_0 area boundary is the main entrance location of the village (Figure 14b). 3) The drum tower location is determined by the probability of 4:3:3 among points A, B, and C. When located at elevation, it will have the advantage of good outlook for purposes of defense. We adjust the location by “geographical domination” analysis (Figure 14c). 4) Based on the results of this analysis, better defensive positions of A_1 , B_1 and C_1 are selected within the search radius (Figure 14d).

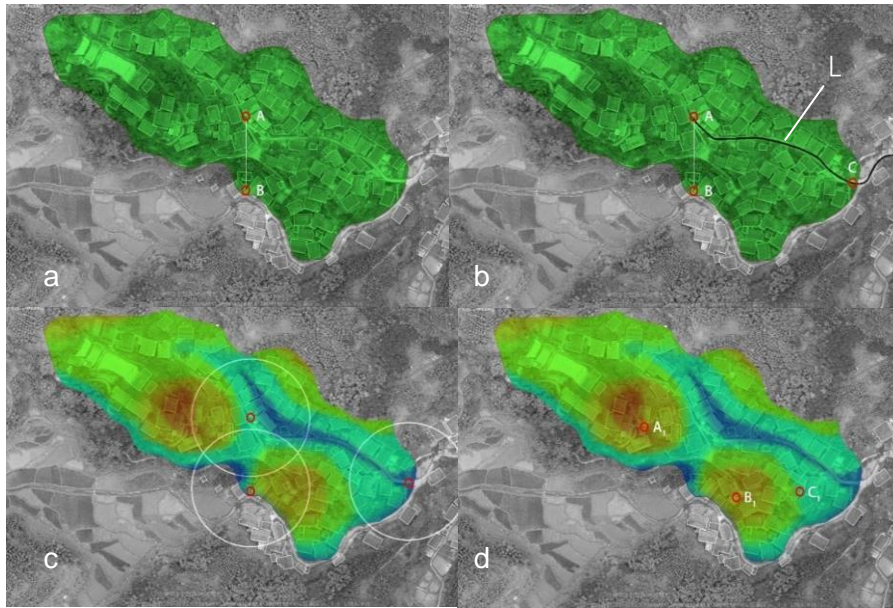


Figure 14: The process for selecting the location of a drum tower

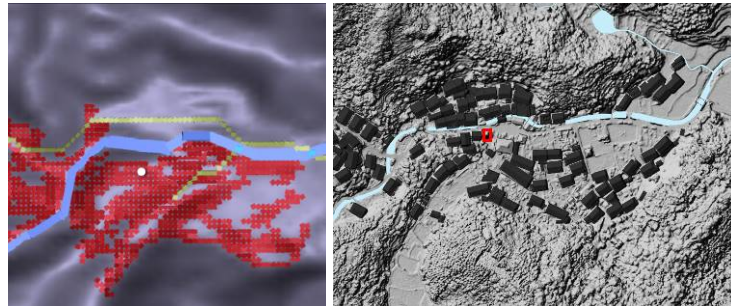


Figure 15: Comparison of simulation result (left) with real position of the drum tower (right)

1.4.2 New Drum Towers & Settlement Expansion

The expansion of a Dong town (Figure 4e) will involve the birth of a new village (Figure 4d) and new drum towers. Culturally, a drum tower is like an invisible magnet, which attracts a cluster of clan (Figure 4c) houses around it. The “magnetism” of a drum tower to attract clan houses weakens as the distance increases. Thus, a Dong village will have a maximum physical area. Any exceedance will eventually lead to an end to village expansion. This will usually result in some clans separating from the original village and building a new drum tower nearby, around which a new village will be established (Figure 16).

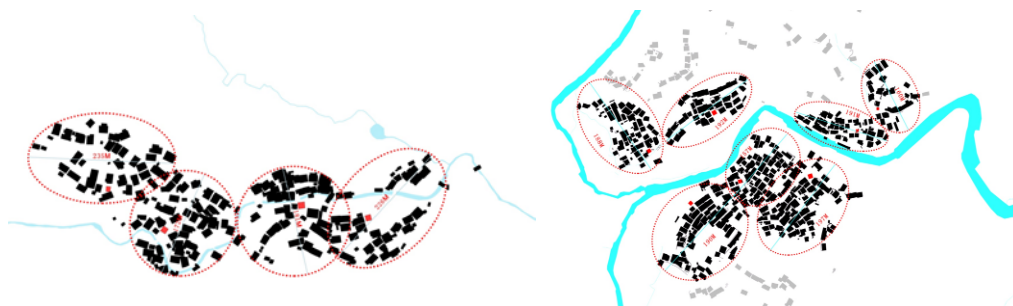


Figure 16: “Magnetism” radius of drum towers in Yutou town (left), and Gaobu town (right). Image

Source: self-drawn

The results in Table 2 show that the “magnetic” radius of a drum tower is fairly regular, being on average 100 meters, and attracting approximately 60 clan houses.

The relationship between Dong villages can also be drawn by analyzing the location of the neighboring drum towers. For the purpose of local alliances, mutual defense and signal transmission, the neighboring drum towers are usually not far from the others, with an average distance of about 100 meters. When villages are located on both sides of the river, a new drum tower is usually sited on the riverside or in highlands for enhanced signal transmission (Figure 17).



Figure 17: Drum tower network locating on both sides of the river

The program uses a drum tower network-based expansion method, based on the data collected on the “magnetism” of existing Dong village drum towers. The search area for a village is roughly an annular zone centered on the first drum tower (Figure 18a). The program calculates the intersection of this ring-shaped area with the G_0 area and selects the block with the largest area. This will then indicate the initial area of the new village G_{2a} (Figure 18b). We set the center of mass of G_{2a} as the initial position of the new drum tower and calculate the intersection of the G_{2a} region with the tower’s likely influence area. This then allows us to draw the expansion zone of the new village, represented as G_2 (Figure 18c-d).

Using the same site selection principles as the first drum tower, such as center of village, riverside, main entrance and physical elevation, we can determine the final site of the new drum tower from the G_2 area.

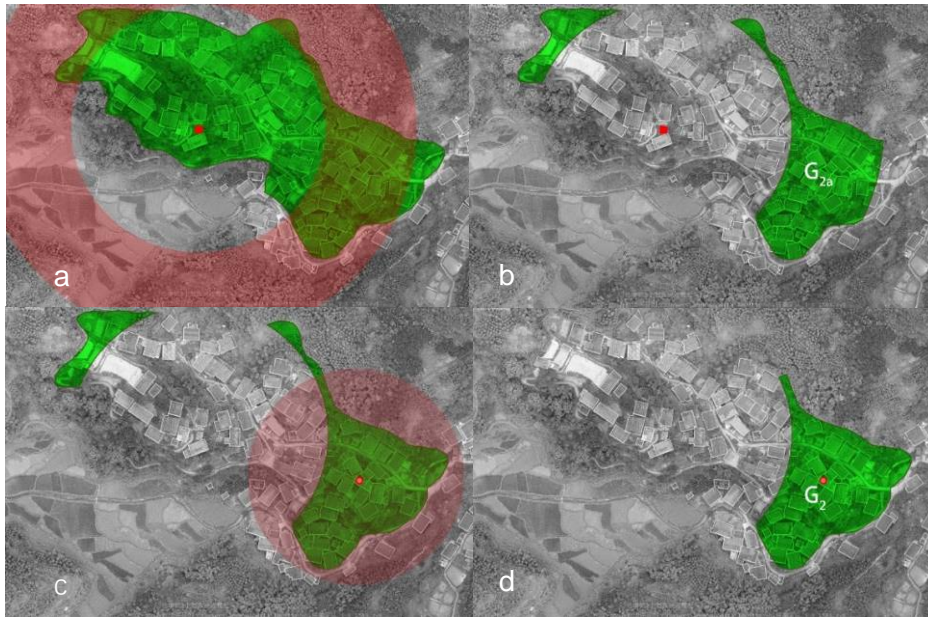


Figure 18: Site selection process of new village.

4 Results

The simulation program introduced in this paper has been used to analyze the site selection and expansion of Dong towns & villages throughout Tongdao, Hunan. The following functions are implemented:

1. Through a comprehensive analysis of the environment, appropriate village and town sites can be selected. Different location strategies can be adopted for different terrain types (Figure 19).

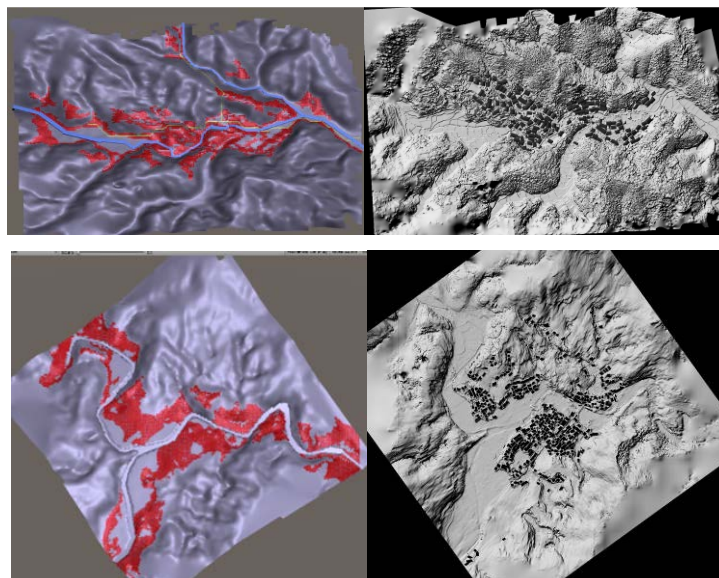


Figure 19: G_0 area of mountain-type town mainly located in sloping land (top-left), while riverside-type mainly in flat land (bottom-left), real layout of Yutou town (top-right), Gaobu town (bottom-right)

- Cultural factors of Dong site selection can be added to the simulation by applying the traditional “Fengshui” concept to the evaluation process. The site that suits the “Fengshui” concept can be selected from all possible site selection areas to determine the location of the first village (Figure 20).

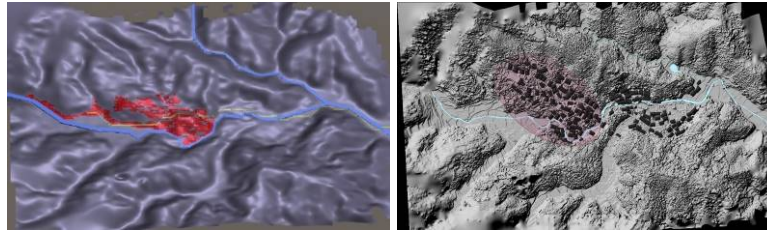


Figure 20: Program selected G1 area (left), first actual village of Yutou town (right, marked in red)

- The ideal location for a drum tower can be determined through analyzing the village area (Figure 21).

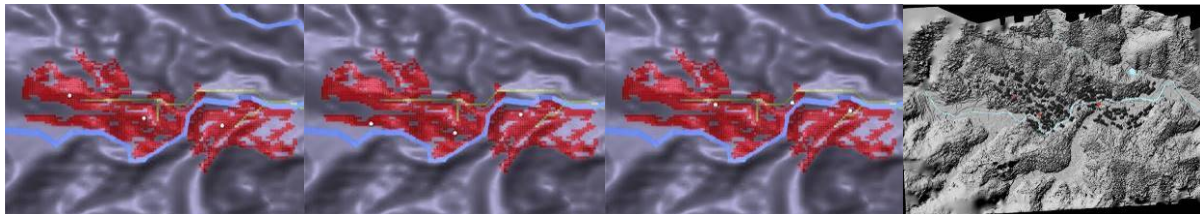


Figure 21, left-to-right: Location of Drum Towers with key factors of center of mass, riverside, main entrance, and the real drum tower's location (marked in red)

- The expansion of the Dong towns can be simulated through the growth of new villages and determining the location of the new drum towers (Figure 22).

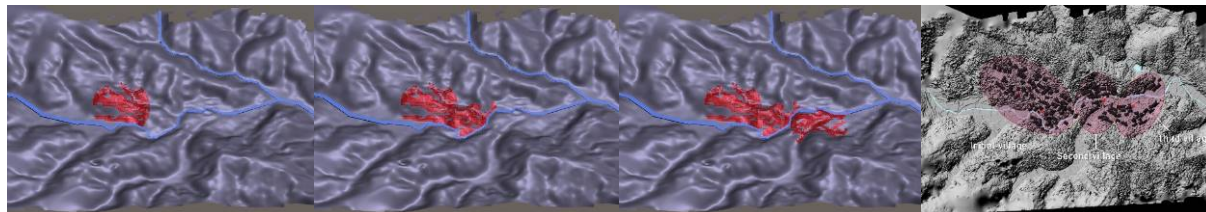


Figure 22, Left-to-right: Simulation of first, second, third villages and the real layout & sequence

5 Conclusions

This paper has detailed a novel planning & design program that can be used to simulate the establishment and growth of Dong towns & villages, through automated “site selection” and “expansion” planning based on varying terrain types. With appropriate inputs based on an analysis of existing, traditional growth patterns, the program can successfully reproduce the layout and expansion sequence of existing Dong towns & villages.

However, the use of this program is not limited to the replica simulation of existing traditional towns and villages, but can be used to guide the planning and design of new rural settlements in China, in a way that captures and preserves culture and history.

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