

## Fire Spread Model for Old Towns Based on Cellular Automaton

GAO Nan (高楠), WENG Wenguo (翁文国)\*\*, MA Wei (马伟)†, NI Shunjiang (倪顺江),  
HUANG Quanyi (黄全义), YUAN Hongyong (袁宏永)

Center for Public Safety Research, Department of Engineering Physics,  
Tsinghua University, Beijing 100084, China;

† School of Geodesy and Geomatics, Wuhan University, Wuhan 430079, China

**Abstract:** Old towns like Lijiang have enormous historic, artistic, and architectural value. The buildings in such old towns are usually made of highly combustible materials, such as wood and grass. If a fire breaks out, it will spread to multiple buildings, so fire spreading and controlling in old towns need to be studied. This paper presents a fire spread model for old towns based on cellular automaton. The cellular automaton rules were set according to historical fire data in empirical formulas. The model also considered the effects of climate. The simulation results were visualized in a geography information system. An example of a fire spread in Lijiang was investigated with the results showing that this model provides a realistic tool for predicting fire spread in old towns. Fire brigades can use this tool to predict when and how a fire spreads to minimize the losses.

**Key words:** old town; fire spread; cellular automaton; geographic information system (GIS)

### Introduction

Old towns represent the cultural sites having high historical, artistic, and architectural value. Fires are disasters that can burn everything into ashes. Methods are needed to protect World Culture Heritages sites like Lijiang. Lijiang is very important to China and to the world because the style and structure of its buildings are of great value to scholars. If fire occurred in these towns, it would result in huge losses to the whole world. Therefore, methods must be developed to protect old towns like Lijiang.

Lijiang includes about 20 600 km<sup>2</sup> with 1.12 million local inhabitants with 23 local minorities. The buildings in Lijiang have their own particular style of the Naxi minority, which follows rules not frequently seen in other places<sup>[1]</sup>. The Lijiang people usually built their houses near beautiful scenes, so each house is close to

others (as shown in Fig. 1). The buildings are mainly made of wood and soil<sup>[2]</sup>. If a fire were to break out, the fire would spread rapidly to other buildings as the wood burns and the buildings would collapse due to loss of the soil that holds the buildings together. Therefore, to protect old towns like Lijiang from fire damage, the mechanism that spreads fires in old towns needs to be studied using computer simulation.

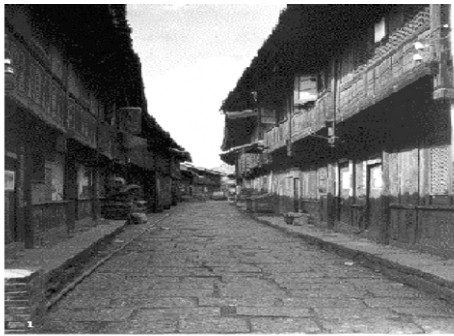
Many scholars have studied the development of city fires and building fires, but they have mainly investigated fires within only one building or very limited spaces. Most of these models can only describe the process and results of fires spreading in one single material. There are few studies concerned with large spaces, e.g., a whole city like Lijiang (including its nearby mountains)<sup>[3]</sup>. Therefore, another method, the cellular automaton model, was used here because it not only can represent the whole process from a macroscopic point of view, but can also describe the details of the fire spreading. This paper presents a fire spread model for old towns based on cellular automaton.

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\*\* To whom correspondence should be addressed.

E-mail: wgweng@tsinghua.edu.cn; Tel: 86-10-62796323



(a) A street in the old town area of Lijiang



(b) Densely built houses in the old town area of Lijiang

**Fig. 1 Lijiang photographs**

## 1 Cellular Automaton Model

The cellular automaton (CA) model generally divides the analysis area into equal-sized grids called cells. Each cell is a basic unit in the fire spread model, with its size determined by the situation. Each cell has the characteristics of the area it belongs to. Each cell has only one state of several limited states according to the local circumstances. The state can change with time. Cells can impact the states of neighboring cells according to update rules applied to all the cells in this system, which are determined from experience.

The cellular automaton method is used in many fields such as transportation, economy, and chemistry. It can also be used to understand the complex mechanics of a spreading city fire in terms of its scale, direction, trends, and so on. This paper presents a fire spread model for old towns based on cellular automaton, which not only can represent the whole process from a macroscopic point of view, but also can describe the specific details of the fire spreading process.

## 2 Fire Spread Model for Old Towns

### 2.1 Parameter arrangement

The first step in the cellular automaton method is to

analyze the structure and geography of the city to determine the parameters used in the fire spread model. Here the old town area of Lijiang is an example.

#### 2.1.1 Cell size

Old areas usually have narrow streets and densely-built houses. In Lijiang, houses are generally 4 m to 7 m long and 2 m to 4 m wide. The streets are generally 3 m wide. The streams running through the old town are about 3 m wide. The numerical accuracy and computational efficiency were balanced with 3 m by 3 m cells in this study.

When two or more materials exist in one cell, the average properties are determined using the area method or the power method. The area method means that in one cell the material with the largest area determines the cell characteristics. In the power method, the cell characteristics are the most important materials in this cell. This model uses both methods in different conditions. The area method is used in most parts of the cities, while the power method is used to cells in important areas, such as the ancient protected buildings area and the old central districts.

#### 2.1.2 Cell characteristics

The city fire spread model advanced by Murosaki et al.<sup>[4]</sup> showed that the building materials, the weather conditions, and the regional characteristics most strongly affect the fire spread. These three factors were defined based on the special characteristics of Lijiang.

##### (1) Factors of buildings

The buildings in Lijiang are mainly built of wood and soil and are generally 1 to 3 floors. But as the town develops, more and more modern buildings are now being built with many new buildings being built with a wide variety of materials. The model must include all these conditions and should be adaptable to future conditions. The people in Lijiang enjoy their lives under the sun and by the streams. Their houses have larger windows 4 m to 6 m in size than in other regions. Thus, they receive more sunshine, but these large windows allow the fire to spread more quickly. The buildings in Lijiang were classified as: (1) wooden buildings having 1, 2, 3, or 5 floors, (2) earthen buildings having 1, 2, or 3 floors, (3) brick buildings having 1, 2, or 3 floors, (4) brick and steel buildings having 1 to 7 floors, (5) steel buildings having 2 to 8 floors, and (6) other buildings like canchas, toilets, and unoccupied buildings. The different buildings have different

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