

# **Automatic Generalization of River Networks Based on Cartographic Knowledge Representation and Reasoning**

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## **Abstract**

River network is one of the most important distributing features group. In this paper, the knowledge in river network automatic generalization include structural river network knowledge, river properties knowledge and generalization rules, and the capturing and formalizing methods of these three knowledge are researched. Following these river network knowledge representation, it brings up a method to build up automatic generalization rules-base of river network. Because the process affects the final result directly, the PRI and weight of using rules are key points of this paper. Ordinal reasoning of production rules system is applied in the river network generalization in this paper, which bases on the known verity and reasons to the conclusion by rules. Then repeat this process, until get a result whether the river is selected. At last, a sample is designed to explain how to use this method to select rivers of a complex river network.

**Key Words: River Network, River Selection, Cartographic Knowledge Representation, Reasoning**

In the digital mapping and GIS domain, drainage is one of the most familiar and various labels. It includes sea, lake (reservoir, pond), river (ditch), and well (spring) etc. Drainage, nature and our society interact. In this paper, the author studies the river selection of the drainage generalization on the map.

## **1. Existing methods of river generalization**

River network generalization has been researched by many scholars, and they have got a great achievement. The Canadian scholar Robert C. Thomson and Rupert Brooks use the perceptual grouping principle of ‘good continuation’, a network is decomposed into chains of network arcs, termed ‘strokes’. The network strokes are then automatically ranked according to derived measures. Deleting strokes from the network following this ranking sequence provides a simple but very effective means of generalizing (attenuating) the network. The Mexican scholar Marco A. Moreno, Miguel J. Torres, Benjamín Martínez, Serguei Levachkine consider the process of change of the scale requires the following stages: Analysis, Automatic Correction of Arc Directions, Classification, Selection/Elimination, Simplification and Enhancement, and establishes rules to preserve the geometric and semantic characteristics of the objects. Liuchun and Cong ai-yan establish a set of rule of river network generalization and use these rules judge the generalization process and chose the arithmetic.

For the river network construction, lots of scholars also make a predominant research. Wu he-hai builds buffer to construct the mainstream-branch relation of river network, get the filiations of every river. But the master river of river system is chosen by rule of maximum length. Guo qing-sheng puts forward a river system automated construction method based on characteristic of river system. First, stores the river network data by means of its topological characteristic; then, searches all nodes whose conjunction degree equal 1, calculates the angle of master river and tributary whose conjunction degree is more than 1, and confirms the direction of every river; At last, confirms the master river and tributary relation according to the “depth” and direction of each river segment.

## **2. Cartographic knowledge representation and formalization of river network generalization**

### **2.1 Spatial knowledge of river network generalization**

The spatial configuration characteristic of river network is various and complicated, their spatial relation of master river and tributary and the distribution of tributaries are different between the river networks that spatial configuration are different. Therefore, processing the river networks data only from the database directly is not

sufficient; we should mine constructed spatial knowledge and summarize rules of generalization operation. In the automated cartographic generalization domain, to process the cartographic features, we focus on the spatial knowledge of cartographic, **spatial knowledge = spatial relation + attribute**. As the river network, to build river network tree structure and actualize automated river selection, the spatial knowledge of river is mainly comprised by the two aspects:

The spatial attributes of river, include the direction angle of river's start point and end point, length of river, information of segments that constitute river etc. These are the basic attribute of river, and also are the basic data to get other spatial knowledge of river.

The spatial relations of river, in the process of river construction and selection, the relation between river object is significant. It is mainly composed by relation of segments, angle of rivers, and the relation of master river and tributary etc.

Furthermore, the quality characteristic of river is important to river selection. For instance, river is perennial river or seasonal stream, whether river is trafficable. These quality characteristic is important to appraise each river.

## 2.2 Two data modal of river network spatial knowledge representation

Because of complexity and extensible of the geographic object, OOP is the most appropriate method to formulate the spatial knowledge of cartographic generalization. Encapsulating spatial knowledge and the operation to this knowledge to property and method of a class adapts to the exploitation and maintenance of the automated cartographic generalization system. In the process of constructing river network, we utilize OOP to abstract two data modals which are the modal based on segment of the river and the modal based on the river object. The ultimately purpose of river network construction is building the river object, the river segment data modal is the temporary data modal of the total process of the construction, but it is the basic data modal of constructing river network.

In the cartographic database, river network data is stored as linear structure (wide river is represented by area structure), there are not any relation between each other. Building the river segment data modal is to get the topological relation of the river segments. The basic elements of topology are NODE and ARC. Building the river segment data modal is to store the river data in the two data structure lists which are named RIVER\_ARC and RIVER\_NODE.

After getting the topological relation of the river network data, the river data are not stored irrelatively any more, the relation of river segments have been get. Then, we should reorganize the data based on the topological relation to set up the river object data modal, and get the constructed spatial information of the river network which are been stored in the data structure list named RIVER\_OBJ. This is the process of river network constructing. Setting up the river object data modal which contains the constructed spatial knowledge of river network is the target of river network construction. The whole process is described as figure1.

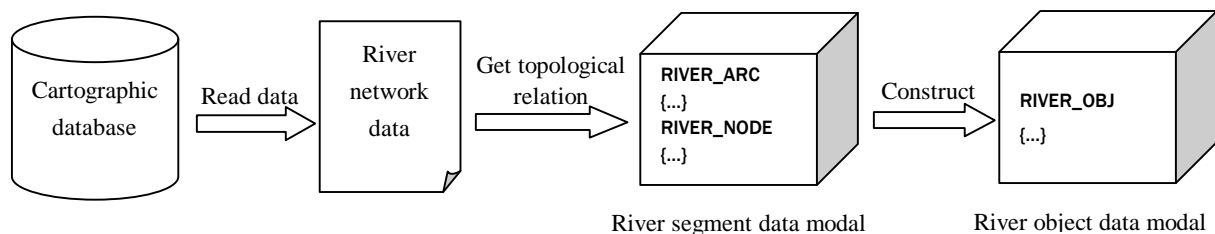


Figure1: The two data modal of river network operation process

## 2.3 The formalization of knowledge and rules of river selection

Usually, the river selection rules are represented by **Production** method, just like “IF...THEN...”, this method can drive and control the selection process. To make the result of river selection reasonable, this paper considers the rule of river selection should be these 3 aspects:

First, the rules should accord with cartographic criterion. But the selection measures should not too rigid, because cartographers can adjust the selection measures according to the different geographical area characteristic. So we design these two tables to solve this problem. Figure2 shows the selection measures of the experimental data (1: 50000) in this paper, and figure3 shows the selection measure of other kind of rivers.

River network density grade	River network density (km/km <sup>2</sup> )	Selection length (mm)	Minimum river distance (mm)
Very dense	>2.0	5	3
Dense	1.0~2.0	8	4
Normal	0.5~1.0	10	5
Sparse	0.1~0.5	12	6
Very sparse	<0.1	Select all	Select all

Figure2. Selection measures of the experimental data (1: 50000)

River style	Selection length (mm)
Seasonal stream	15
Interrupted stream	2
Underground river	1

Figure3. Selection measure of other kind of rivers

Secondly, the river's significance should be considered. This is a fuzzy factor, and it is difficult to be formulized by computer. In this paper, we use different number to represent the river's different significance. This paper put forward three rules to identify the significant river according to cartographical criterion and the instances possibly occur in the cartographical compilation. A river is one of these instances should be deemed significant river, and should be selected.

**RULE1.** A river which locates the margin of the total drainage area is significant river.

**RULE2.** A river which connects lakes or flows into sea is significant river.

**RULE3.** In a river's drainage area, the grade of habitations is high and quantity is big, or the river is Boundary River, we deem this river is significant river.

Thirdly, the figure characteristic of total river network should be considered. According the traditional viewpoint, the figure characteristic of total river network is classified 7 kinds, such as dendritic drainage, feather drainage etc. But the computer identifying these figure characteristics is a complicated problem. This paper dose not research how to identify these figure characteristics, thus, we focus on how to preserve the contrast between the left and right tributaries after river selection.

### 3. Structural knowledge acquiring of river network

#### 3.1 The river network construction based on identifying master river

Many researchers attach importance to river network (none-circle) construction, but they sometimes divide the master river and tributaries, and deem the river whose length is maximum is master river, then get the tributaries of all levers. This paper integrates the master river and tributaries of all levers, considers that the master river of total river system is the 1st grade river, and its branches are the 2nd grade rivers, the rest may be deduced by analogy...In this way, the construction of total river network is the iterative process that get the rivers of all levers. According to this idea, the process of constructing river network would be including these five steps:

1. Utilize the arithmetic which is named Graph Search to search from estuary of river network, save the paths from the estuary point to all head points, and add them to the LIST1; record the length of path, the intersected point of rivers and average angle of these points through the whole path.
2. Identify the master river, use the arithmetic of identifying the master river to get master river, then delete it

from LIST1 and add it to LIST2.

3. Compare the river objects which are remained in the LIST1 and the master river, delete its segments which are also the part of master river, sequentially, we get the preparative rivers from which the next grade river is selected. Get the information about the master river and tributaries and renew the information of preparative rivers.
4. Repeat step2 and step3 till the LIST1 is empty, namely, all river segments data have been transformed to river object data modal, and the rivers are classified.
5. At last, get all tributaries of each river by the ID of the intersected point. Further more, get other constructed information.

In step 1, the rivers are identified simply, namely, we find the all segments from estuary of the total river network to river heads, but these are not constructed river objects, we should get master rivers of total river network, then get all levers rivers of the river network.

### 3.2 The further integrating of river network structure

#### 1. Acquirement of the direction of tributary

The figure 4 shows auto judgment of left or right. The river CA and EB are tributaries of river FBAD, we can judge whether the tributary is left or right through this conclusion:

$$0 \leq a \leq \pi, \begin{cases} a + \pi < b < 2\pi \text{ 或 } 0 \leq b < a, & \text{为右支流} \\ a < b < a + \pi & \text{, 为左支流} \end{cases}$$

$$\pi < a < 2\pi, \begin{cases} a - \pi < b < a & \text{, 为右支流} \\ a < b < 2\pi \text{ 或 } 0 \leq b < a - \pi & \text{, 为左支流} \end{cases}$$

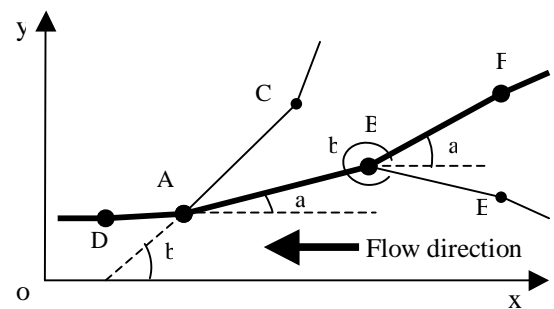


Figure4. Auto judgment of left or right

#### 2. Acquirement of the depth of river's subtree

Depth of river's subtree is the lever that this river's "offspring". The depths of all river's subtree are initializes as **DEP** = 1, the method of detecting depth of each river's subtree is as follows:

**Step1.** Search all river objects (named **RIVER**) whose depth equal to **DEP**, if **RIVER**'s upper river (named **UPRIVER**) is existent and its depth equal to **DEP**, let **UPRIVER**'s depth plus 1.

**Step2.** Let **DEP** plus 1, repeat **Step1**, till the upper river of **RIVER** is not existent, namely, **RIVER** is the master river of total river network.

### 4. River selection based on rules and cartographic knowledge

#### 4.1 The reasoning framework of river selection

Based on the cartographic knowledge of river network, we set up the rule base of automated cartographic generalization. Each rule in the rule base is abstracted as a function, and we design the flow of using the rules, that is the reasoning process of data-driven. This reasoning process influences the result of river selection directly, so the cartographical knowledge and PRI of rules are needed considered roundly. The reasoning mode of Production System is data-driven reasoning; it starts from known fact, get result via rules, and accord with characteristic of river network generalization, and it is adopted by this paper. Firstly, select the river which can touch off the first rule of the reasoning process, thereby, the reasoning process is started. Then add the new instance to the database and touch off the next rule of the reasoning process. Repeat these steps till get the result that whether the river is selected (figure 5).

The two important facts of influencing the river selection result are the acquirement of constructed knowledge of river network and the reasoning based on cartographical rules. Now, as the figure 6 shows, we introduce the method of river selection.

**Step1.** As the figure 6 shows, river **AB** is the master river, get one of its tributaries whose depth of river's subtree is

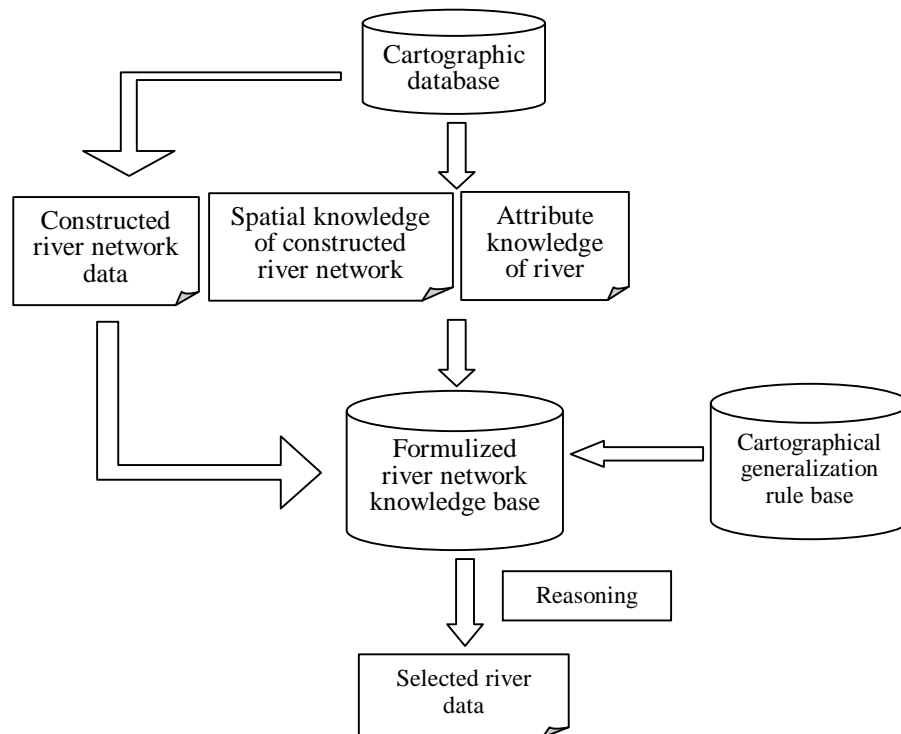


Figure5. The reasoning framework of river

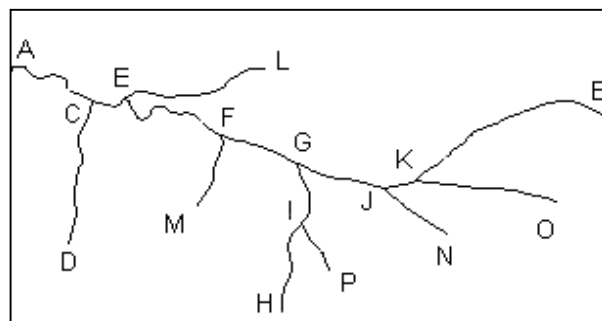


Figure6. River selection

1 (such as river **CD**), if there are not tributaries whose depth is 1 any more, exit.

**Step2.** Get the attribute of river **CD** (such as Seasonal stream or perennial river), and select respective measures.

**Step3.** Get length and river distance of river **CD**, and compare them with the measures, if they are up to the mustard, the river **CD** is selected, and turn to step 1, else continue.

**Step4.** Estimate the significance of river **CD**, if river **CD** accords with one of the 3 rules that be mentioned in section 2.3, it is the selected river, else, add river **CD** to deleted river list.

In order to protect the structure characteristic of river network when rivers fit the selection standard and importance, the rivers that putted in delete list aren't be deleted, until next step of consequence. This principle is shown as figure 6. If river **EL** fits neither selection standard nor importance, but because of **AB** is the only one right branch, **EL** should be reserved, for river net's structural simulation after generation. The process of whole consequence as figure 7 shows.

As figure 7, the finally temp delete river list TempDelList, rivers in the list are not always be deleted. Because of before consequence, we only considered the selection standard and river's importance. The relationship between left and right branch should be considered. In this paper, the author bring forward a consequence principle of integer structural simulation, the basic rule is keep the contrast relationship after consequence. So, there are three conditions

shown as figure 8. N means number of rivers before consequence. D means the number of rivers that in Temp delete list. S means number of rivers that the length ratio of master river and tributary is less than 0.1 for better universalism, differentiate left branch and right branch with subscript 1, 2.

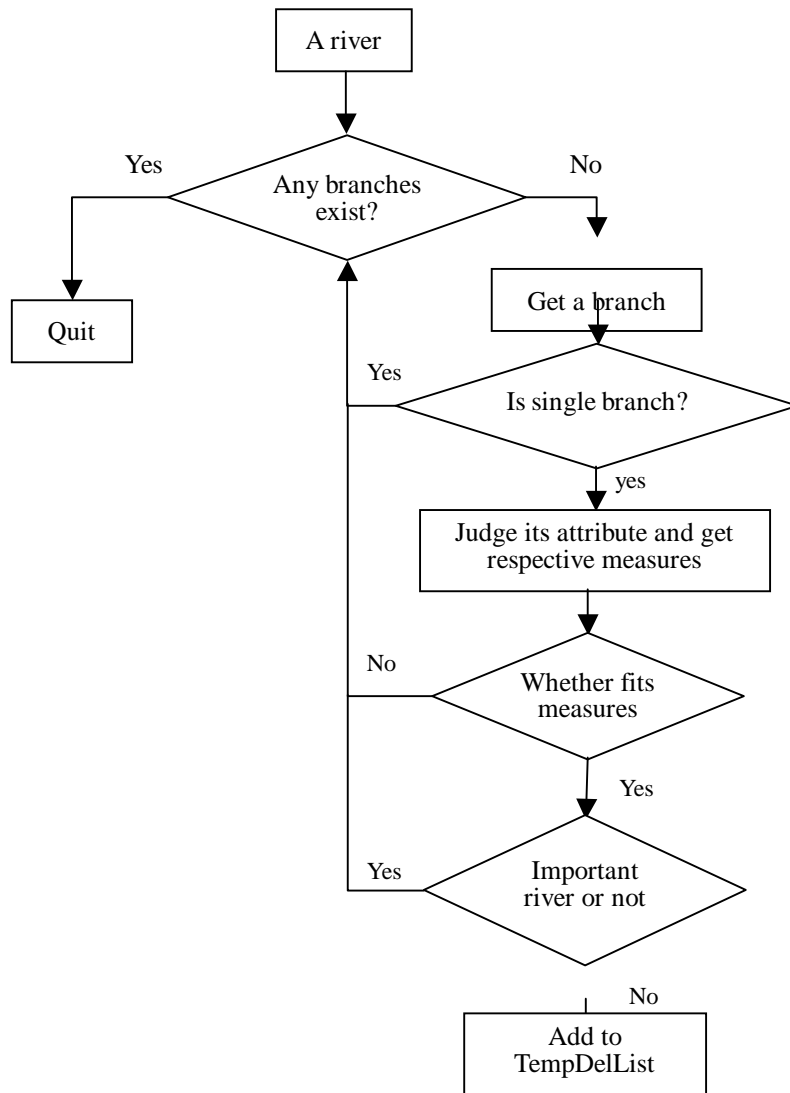


Figure7. Reasoning framework of river selection

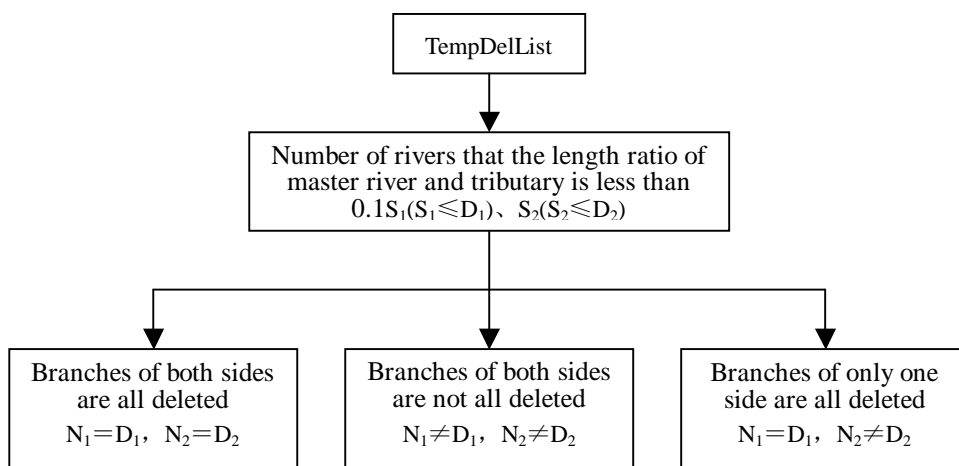


Figure8. Reasoning framework of preserving structure characteristic

## 4.2 The results of experiment

The multiformity of river's configuration causes the complex and incertitude. According to methods of knowledge obtain and "knowledge principle". We have done an experiment of tow map's data (at scale of 1:50000). We compare resource data of igure9 and two results figure10 and 11 results of selection by two different methods, then find out knowledge based judgment introduced in this chapter is reasonable and effectively.

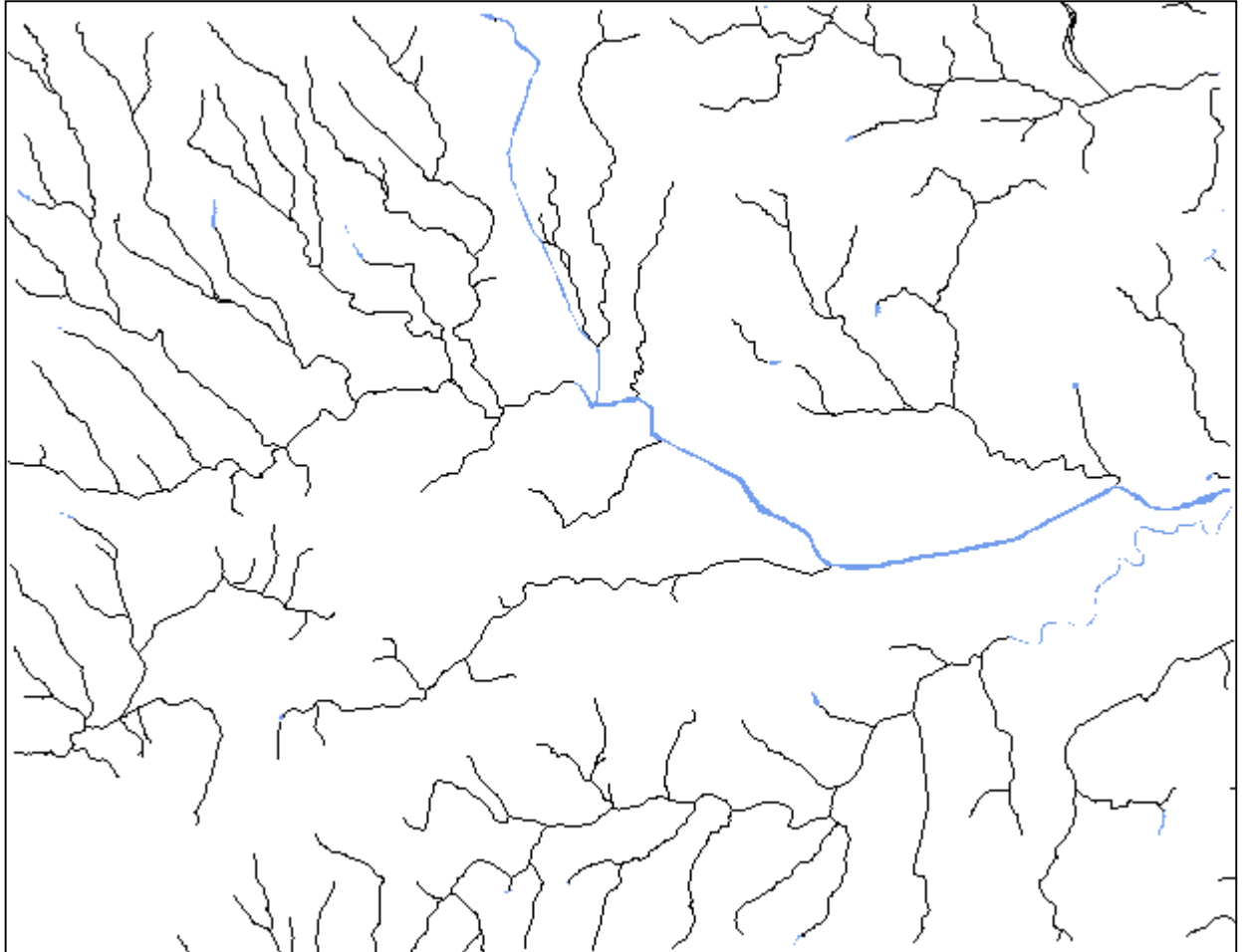


Figure9. Original figure of experiment

Figure10. Two results of different selection methods

Common parameter	method	number of selection	selection rate	largest length of deleted river (m)	result map
		Extraction law			
		99	70.7%		
Sum of river is 140 Length measure 14mm Distance measure 5mm	Methods of standard	98	70.0%	697.1	3—16
	methods of consequence	103	73.6%	1214.5	3—17

In this chapter, we discussed methods of obtain knowledge of river structure spatial information and knowledge based consequence. The results of experiment are given. According to the results of experiment, method of knowledge-based consequence is effectively in automatic selection of rivers; it used to keep the integer of river net's structure, especially in the condition of contrasting on left and right side. In the experiment, the author considers that knowledge of vision play a key role in river's selection. The method introduced in this chapter is one of the methods of trying to simulate vision knowledge. Further more conclude and sum up may bring better graphic effect.

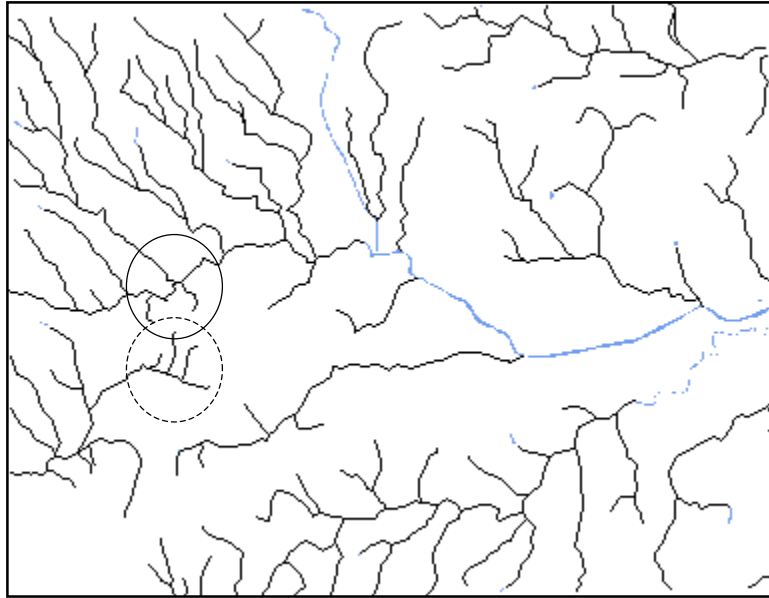


Figure11. The result of selection based on measure

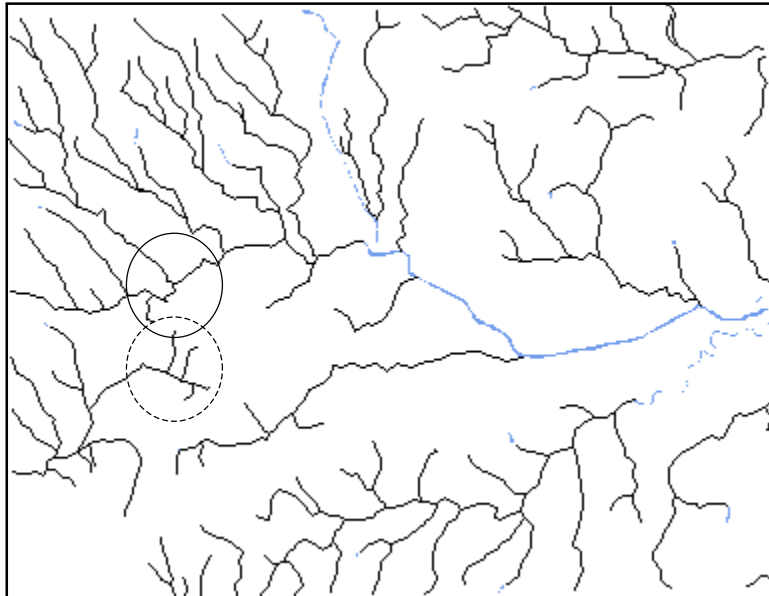


Figure12. The result of selection based on reasoning

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