Framework of Pattern Recognition Model Based on the Cognitive Psychology

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1 Introduction

With the technology development and integration of photogrammetry, RS and GIS going further, a new branch of information science, geoinformatics rose and has been developed rapidly. The integration of geoinformatics with the earth science, information science, computer science, artificial intelligence, expert system etc. forms a huge complicated system concerning the acquisition, processing, storing, representation, distribution and application of information about the earth. Only for the image information processing, a great progress has been made on the aspect of technology and algorithm during the past several decades, but there still exist a lot of difficulties concerning the automatic classification, pattern recognition, image analysis and understanding, the representation of information and the utilization of knowledge etc. Generally speaking, the knowledge level on these issues lags far behind the human's cognitive level at present. Taking the pattern recognition from image as an example, a number of difficult issues arise in visual pattern recognition [1].

The origin and development of cognitive science has a history of several decades, but it is only in recent years that the theoretical research about cognitive science has attracted enough attention from the field of geoinformatics [2]. At present, the theory of cognitive science has been generally acknowledged as the important components of fundamental theory of geo-spatial information science. In this paper, three theoretical models of visual pattern recognition based on the basic theory of cognitive psychology, which is the essence of cognitive science, are built, and the related visual perception mechanism is discussed.

KEY WORDS perception; perception processing; cognitive psychology; pattern recognition; superiority effect
ABSTRACT According to the fundamental theory of visual cognition mechanism and cognitive psychology, the visual pattern recognition model is introduced briefly. Three pattern recognition models, i.e. template-based matching model, prototype-based matching model and feature-based matching model are built and discussed separately. In addition, the influence of object background information and visual focus point to the result of pattern recognition is also discussed with the example of recognition for fuzzy letters and figures.

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2 About the cognitive psychology

Cognitive psychology is one of the branches of psychology, and it is also the main component parts of cognitive science. Cognitive psychology takes the human brain's mechanism for information processing as its theoretical core, i.e. comparing the human brain with the computer, and treating the human brain as an information processing system that works like a computer. The main research area of cognitive psychology concerns the psychological or cognitive process of perception, attention, mental image, memory, thought, language learning and pattern recognition as well as the organization of knowledge etc. The main purpose of the above research is to reveal the human's internal psychological mechanism[^3^4].

Generally speaking, the cognitive process includes the procedures of information acquisition and information processing (i.e. the thought) as well as the subjective information generation (also called regeneration). To understand this issue in a narrow sense, cognition is the process of knowledge state changes, i.e. the process of subjective information generation. Fig. 1 shows the above relationship and the general model of cognitive process.

![General model of cognitive process](image)

3 Perception and perception processing

Cognitive psychologists treat the most cognitive process as "perceptive". Perception process accepts the sensation input and transforms it into abstract codes. In the field of cognitive psychology research, there exist two opposite theories about the cognitive process of perception. The first standpoint thinks that the perception has close relationship with human's knowledge and experience. The second standpoint thinks that perception is direct and has nothing to do with the knowledge or experience. However, with the development of cognitive science research going deep, cognitive psychologists have enough reasons to think that perception depends on the past experience and knowledge, perception information is the result of mutual action between reality stimulation and memory information.

Since the cognitive psychology stress the importance of past experience and knowledge as well as the reality stimulation about the outside world in the process of perception generation, perception process should include two mutually related processing approaches, i.e. the bottom-up processing and the top-down processing. The former starts with the external stimulation and focuses on the analysis of smaller perception elements first and then moves to the perception analysis of larger elements. After a series of processing, it gives the explanation of sensation stimulation. The latter is a knowledge-guided perception processing, and the higher level processing controls the lower level processing. Lindsay and Norman (1977) called the former data-driven processing and the latter concept-driven processing. They are two approaches opposite to each other in processing direction. Without the effect of stimulation, the top-down processing can only bring about illusion. On the contrary, it is hard to cope with the situation of double meanings or uncertainty for some stimulation if only based on the bottom-up processing. If the united perception result is expected, it is necessary to integrate the two approaches.
4 Pattern recognition

The perception research of cognitive psychology mainly concentrates on the issue of pattern recognition, especially on the visual pattern recognition. Human's pattern recognition can be treated as a typical perception process, which depends on human's available knowledge and experience. Modern cognitive psychology has presented several theoretical models about Human's pattern recognition, such as template-based matching model, prototype-based matching model and feature-based matching model, some of which are greatly affected by the artificial intelligence (AI). A further research and understanding of these theoretical models is meaningful to the pattern recognition issues concerning the field of computer vision and geoinformatics.

4.1 Template-based matching model

The core of template-based matching model is that in human's memory there should exist plenty of various duplicates about the real world pattern, which are called templates and formed from the past living experiences. The real world patterns and the templates are corresponding to each other. When an outside stimulation affects human's sensory organ, the stimulation information will be coded first and then compared with the stored templates in order to find the best matching pair. The template with the best matching is probably the pattern of that stimulation, so the pattern can be recognized.

![Diagram](https://via.placeholder.com/150)

Fig. 2: Template-based matching model

According to the basic viewpoint of template-based matching, it is necessary to have the corresponding templates stored in the memory in advance in order to recognize a special pattern. However, the real world patterns are various and may be different in shape, size and direction etc., it means that each distinct case has a corresponding template, otherwise, the recognition of pattern will fail. In this case, in order to realize pattern recognition correctly, people are required to store countless templates in the memory, which will greatly increase the burden of memory, and it is also contradictory to human's high flexibility in the process of pattern recognition. In order to overcome this shortcoming, some scholars suggest adding a preprocessing process to the template-based matching, that is, adjusting the shape, size and direction of stimulation in the initial stage of pattern recognition, and standardizing them in order to greatly reduce the number of templates. To do this seems logical, but the problem is how to adjust the stimulation from outside world if we have no idea what the pattern is to be recognized in advance.

In fact, template-based matching is a kind of bottom-up processing model. In order to make the preprocessing efficiently, the top-down processing model should be considered. Human's perception contains the mutual relation between the bottom-up and the top-down processing mechanism, only when the template-based matching is integrated with the mechanism of the top-down processing, the matching model can be completed. Fig. 2 shows a relatively completed template-based matching model.

4.2 Prototype-based matching model

The prototype-based matching model was presented in order to remedy the shortcoming of the prototype-based matching model. The main characteristic of the template-based matching model is that, what stored in human's memory is not thought to be the templates of outside world pattern, but is the prototypes of real world objects. These prototypes reflect the basic features of a certain kind of
objects. For this reason, the prototype-based matching is also called component-based matching sometimes.

According to the viewpoint of the prototype-based matching model, outside stimulation is only needed to compare with the prototypes during the pattern recognition process. Since the prototype is a kind of summarized token, so the accurate matching of above comparison need not to be strictly satisfied, only approximate matching is required. Even if there exist some differences in shape, size and direction for certain objects, all these objects can still be recognized through the matching with prototypes, it means the new and unfamiliar patterns can also be recognized so long as the related prototypes are available. Fig. 3 shows a kind of prototype-based matching model.

4.3 Feature-based matching model

Pattern consists of a certain number of elements or component parts by a specified relationship. These elements or component parts are usually called features, and the relationship among them can also be called features sometimes. All complicated stimulation is thought to be composed of differentiated and separated features in the feature-based matching model. The calculation of feature’s existence and then comparing this calculation value with the list of known feature’s value can accomplish the pattern recognition.

The feature-based matching model emphasizes on the importance of feature and feature analysis. The successfulness of feature-based matching depends on the separation degree of stimulation. The status and function of the features here are similar to that of template in the template-based matching, i.e., the feature can be treated as a tiny template or a component template. But the feature-based matching is different from the template-based matching after all. The former has certain advantages.

1) The recognition in this case is based on the features and their relationships, so it is not necessary to consider the stimulation changes caused by the differences of size, shape and direction etc., thus one can avoid the difficulty and burden of pre-processing process and make the recognition more flexible.

2) The same features can appear in different patterns, which can greatly lighten the burden of memory.

3) Because feature extraction, analysis and information integration are all required for the recognition purpose, the feature-based matching process is provided with the learning ability in certain degree.

But unfortunately, that different patterns have the same features will make the recognition hard to realize, and even cause the wrong recognition. However, compared with other pattern recognition models, the feature-based matching model does have greater flexibility.

5 Object background and superiority effect

The purpose of the research on object background is to find out the possible effect of object background information on the recognition result during the visual perception process. In fact, in many cases of pattern recognition process, the object back-
ground information can be used for the processing of feature analysis. Fig. 4(a) shows a set of handwritten form letters and figures. The top stimulation in this figure can be regarded as "15" or "is", the recognition results here totally depends on their background information. From this example, we know that the analysis of background information is beneficial for obtaining a correct result in pattern recognition. The cognitive psychologists call this phenomenon "Superiority Effect".

![Example](https://example.com/figure4)

**Fig. 4 Fuzzy letters and figures**

For further study, another set of fuzzy letters and figures are taken as an example. Fig. 4(b) is a set of printing form characters. When the top character in Fig. 4(b) is recognized individually, it is hard to determine whether it is a figure "0" or an English letter "o". However, when it appears in a string of figures or an English sentence, it can be correctly recognized easily. This further explains the importance of context information to the result of pattern recognition and the superiority of entirety processing.

The use of background information does not mean that the "Superiority Effect" is always available. During the visual cognitive process, the difference of visual focus point will greatly affect the recognition result. If the position of visual focus changes in the context or graph, the "Superiority Effect" will not appear sometimes. In this case, the efficiency of pattern recognition will also be affected. The concept of visual focus point is called "selective attention" in the cognitive psychology.

The research of "Superiority Effect" is one of the hot spot in cognitive psychology at present. On one hand, it concentenately reflects some important issues on perception and pattern recognition, such as the organization of perception, the effect of experience and knowledge, the mechanism of bottom-up processing and top-down processing etc.; On the other hand, the "Superiority Effect" can help us to understand the human's instinct that is different from the machine pattern recognition. To further understand the "Superiority Effect" needs to integrate the viewpoints of psychology, physiology, artificial intelligence and some other disciplines.

### 6 Conclusion

From the perspective of geoinformatics, the main purpose of theoretical research of pattern recognition model based on the cognitive psychology can be concluded as follows:

1) understanding the human's visual cognitive mechanism;

2) Taking this visual cognitive mechanism as the theoretical guidance, to develop an image understanding system which can automatically constitute the scene description from the image data.

At present, our understanding degree and the research profundity to the visual cognitive mechanism lag far behind the development of the means of image information processing. The basic theory of human's visual cognitive mechanism and computer vision is still in the process of searching and forming. The research of fundamental theory in this field should be strengthened.

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