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A Study on Hybrid Approaches in Image Recognition System

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Abstract—**Hybrid approaches have been applied widely in image recognition system to adapt the increasing requirement of real-time and high accuracy and there are a lot of successful hybrid image recognition algorithms. To use hybrid approaches more effectively, some basic research about it is very necessary. This paper analyzes current typical hybrid samples, then presents basic hybrid image recognition patterns and evaluates their performance about real-time, accuracy, robustness, expandability and flexibility. At last a developing hybrid image recognition system would be introduced as a sample.**

Index Terms— **Image Recognition System, Hybrid, Real-Time, Accuracy, Robustness, Expandability, Flexibility**

I. Introduction

When developing an embedded system of image recognition, we usually face three main challenges: 1) real-time, it means the system must finish specific task in limited time; 2) accuracy, it means high recognition rate and low fault recognition rate; 3) robustness, it means the system should keep high recognition capability in different situations. Up to now, people have developed a lot of image recognition algorithms that usually can reach good accuracy in some situations, for example, AI network, semantic network, SVM and so on. But there appears to be no single, uniform approach to resolve the three problems at the same time. So people have to combine multiple algorithms to improve image recognition system's capability which is usually called the approach "Hybrid".

People have done a lot of research on hybrid image recognition approaches for many years and a lot of different hybrid systems have been provided which usually can reach better accuracy and robustness than pure systems. But most researches focus on special applications while general theories are still in absence now. This paper gives a general summing-up about current hybrid approaches which include some common patterns and estimates about every pattern's real-time, accuracy and robustness. On the other hand, since hybrid approaches have brought huge challenges to system's architecture. It has become another research focus that how to design a hybrid image recognition system with good expandability and flexibility. This paper gives these patterns' estimation about expandability and flexibility.

At last the paper introduces our developing rear vehicle recognition system based on images, it combines many hybrid patterns and gets good accuracy as well as robustness. And an analysis about the system's expandability and flexibility would be provided.

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II. Related Work

There have been many research efforts about hybrid image recognition algorithms. Most of these efforts address specific problems. Some representative samples of them can be outlined as follows: [1] Gunther Heidemann et al. present hybrid architecture for 3D-object recognition based on the integration of neural and semantic networks, which used a neural object recognition system to generate object hypotheses and a semantic network to verify them. [6] Ping Zhang et al. propose a hybrid neural network and tree classification system for handwritten numeral recognition, which used a four-layer feed forward neural network with back propagation learning algorithm as a coarse classifier and used a decision tree as a fine classfier. [7] Xiang Gao and Ravin Balakrishnan present a hybrid gesture interface framework that combines on-line adaptive gesture recognition with a command predictor, and the hybrid adaptive system significantly improved overall gesture recognition performance. [8] Teng Long et al. propose a novel hybrid system for one stroke style cursive handwriting character recognition. An on-line recognizer that can tolerate large variations in stroke shape and position and an off-line recognizer that is not sensitive to variations of stroke order are combined in this system.

Above are some samples in which some methods are combined simply to get a new hybrid method. In fact there are still many samples in which hybrid structure are very complex. [10] Nageswara S.V. Rao et al. describe a system capable of recognizing and learning two-dimensional patterns. It utilizes compemrns of symbolic and neuromorphic type and these components make up of a

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complex system. Another sample is [11]. In it Srinivas Gutta et al. design several different hybrid architectures for the classifier of a face and hand gesture recognition system.

III. HYBRID PATTERN

Current hybrid patterns can be divided into two main parts according to complexity. One is simple hybrid pattern set that includes basic hybrid patterns and another is complex hybrid pattern set that includes various combinations of simple patterns. This paper would mainly focus on simple pattern set.

Comparing the input and output of each sub-algorithm in hybrid algorithm, two simple patterns can be obtained. One is sequence pattern, in which one algorithm's output is another algorithm's input. Another is parallel pattern, in which all algorithms have the same input and equivalent output.

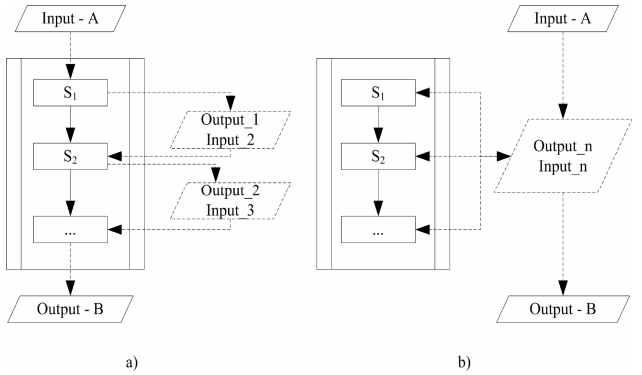

Fig. 1. Software Structure of Sequence Hybrid Pattern. a) is CHAIN sequence hybrid pattern, b) is ITERATIVE sequence hybrid pattern. Real lines are control flows and broken lines are data flows.

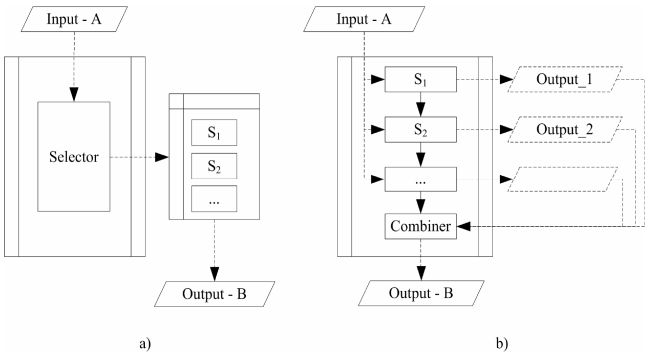

Fig. 2. Software Structure of Parallel Hybrid Pattern. a) is SELECT-DO parallel hybrid pattern, b) is DO-COMBINE parallel hybrid pattern. Real lines are control flows and broken lines are data flows.

A. Sequence Pattern

A vivid description of the pattern is an algorithm chain. In sequence hybrid pattern all algorithms would be executed one by one and the latter one can work based on the former one's result. There are two typical structures for sequence hybrid pattern – CHAIN and ITERATIVE.

1) CHAIN Sequence Hybrid Pattern

This pattern usually has a predefined sequence process which has many steps, and each step's end is another's start. For each step, there exists an algorithm. These algorithms are usually different. When every step uses the best algorithms, the process would become optimal. Some typical examples of this pattern have been shown in [1] [2] [3] [4] [5].

Usually the pattern has the following features:

a) There exist an input set A and an output set B, and there exists a mapping from A to B.
b) There exist n algorithms (S1, $S_{2...}$ S_n). (n>=2)
c) Only one algorithm can use A as the input set and only one algorithm can take B as the output set. For others, one's output is another's input. And no any two algorithms have the same input set or output set.
d) After all algorithms have been executed in a sequence, the mapping from A to B has been implemented.

2) ITERATIVE Sequence Hybrid Pattern

This pattern usually has close relation with coarse-fine refinement strategy. Generally there exist some different algorithms, which can finish the same task, and their outputs are the same kind of data with input. So iterative of these algorithms can implement coarse-fine strategy. A typical example of this pattern has been shown in [6].

Usually the pattern has the following features:

a) There exists an input set A and a mapping from A to A.
b) There exist n algorithms (S1, $S_{2...}$ S_n). (n>=2)
c) These algorithms have equivalent function but different performance.
d) Any algorithm' output is a subset of its input.
e) Every algorithm takes A as input set and after it has been executed its output would be as the new A.
f) After all algorithms have been executed in a sequence, the mapping from A to B has been implemented.

B. Parallel Pattern

In parallel hybrid pattern there are many algorithms, which can finish same task and have same input and output, and there is an additional manager which is used to schedule these algorithms or manage their results. There are two typical structures for parallel hybrid pattern – SELECT-Do, Do-COMBINE.

1) SELECT-Do Parallel Hybrid Pattern

This pattern usually has another name – Adaptive Pattern. It means there are many different algorithms, which have the same input and output and can finish the same function. A main characteristic is that only one among them can be selected to run. A selector is the core of this kind of pattern, which can evaluate all algorithms and select the most appropriate one adaptively. A typical example of this pattern has been shown in aticle [7].

Usually the pattern has the following features:

a) There exist an input set A and an output set B, and there exists a mapping from A to B.
b) There exist n algorithms (S1, $S_{2...}$ S_n). (n>=2)
c) These algorithms have equivalent function but different performances and anyone can implement the mapping.
d) There exists a selector, which can estimate all algorithms.
e) The selector can select only one algorithm to execute and the mapping would be implemented.

2) DO-COMBINE Parallel Hybrid Pattern

This pattern has many different algorithms which have the same input and output and can finish the same function too. But all the algorithms would be executed and combiners would combine these outputs to get one final result. Some typical examples of this pattern have been shown in aticle [8] [9].

The pattern has the following features:

a) There exist an input set A and an output set B, and there exists a mapping from A to B.
b) There exist n algorithms (S1, $S_{2...}$ S_n). (n>=2)
c) These algorithms have equivalent function but different performances and anyone can implement the mapping.
d) There exists a combiner which can fuse all algorithms' results.
e) All algorithms would be executed and the combiner would fuse all the results to get the final result based on rules.

IV. PERFORMANCE ANALYSIS OF HYBRID PATTERN

All these hybrid patterns can help people to improve system's accuracy and robustness, but they have different characteristics. And when developing a complex system, people usually need to combine many hybrid patterns to get an optimal system. If people can know their performance very well, this work would become easier. Then an analysis about real-time, accurcy and robustness would be very important.

Usually people expect software can adapt future requirement variety with little cost. This demands software architecture should be expandable for new requirement and flexible for change. Then an analysis about expandability and flexibility would be very important too.

Then this paper would give these analysises and provide a comparision.

A. CHAIN Sequence Hybrid Pattern

The software structure of this pattern would include two main elements: an algorithm pool with many algorithms that satisfy the pattern's demand and a predefined process with many different steps.

This pattern may select a best algorithm for each step when system is developed, so it can get better real-time and accuracy. But it can only get normal robustness because there are still some situations in which even the best algorithm cannot work well.

It is very difficult to expand the pool because the count of algorithms in the pool is as many as steps of process while the process is fixed. And once the process has been modified, the whole system architecture needs to be changed.

It is easy to modify one algorithm in the pool while other elements of pool would not be affected.

B. ITERATIVE Sequence Hybrid Mode

The software structure of this pattern would include two main elements: an algorithm pool and a predefined process with many equivalent steps.

TABLE I
PFORMANCE ANALYSIS OF PATTERN - 1

Patterns	Real-Time	Accuracy	Robustness
CHAIN	High	High	Normal
ITERATIVE	Normal	High	High
SELECT_DO	High	High	High
DO-COMBINE	Low	High	High

TABLE2
PERFORMANCE ANALYSIS OF PATTERN - 2

Patterns	Expandability	Flexibility
CHAIN	Low	Normal
ITERATIVE	High	High
SELECT_DO	High	Normal
DO-COMBINE	High	Normal

This pattern needs to process the same data for many times, so it is difficult to get a good performance. But it can make the algorithm more accurate and robust.

It is very easy to expand this kind of structure by adding algorithms to pool and adding steps to process. And modifying any algorithm would not affect others.

C. SELECT-DO Parallel Hybrid Pattern

The software structure of this pattern would include two main elements: an algorithm pool and a selector that can evaluate all algorithms and execute some one.

This pattern always can select a best algorithm to execute for current situation if there is an algorithm in pool that can satisfy requirements. Then we can get expected real-time, accuracy and robustness. But it is difficult to dynamically evaluate every algorithm in some situation before running.

When software structure needs to be expanded, people just need to add algorithms into pool and add corresponding evaluation part to the selector. And when an algorithm is modified, an adjusting of the selector is needed too.

D. DO-COMBINE Parallel Hybrid Pattern

The software structure of this pattern would include two main elements: an algorithm pool and a combiner that can combine all algorithms' results.

This pattern needs to execute all algorithms and can get optimal result, so it can get same accuracy and robustness with SELECT-DO pattern.

Because evaluating results seems more easily than evaluating algorithms, this pattern is easily used. But there is a terrible shortage that real-time would be sacrificed.

When some algorithms are added into pool, combiner needs to be modified, maybe changing some rules or

adjusting a formula. And when some algorithms are modified, combiner needs to be adjusted too.

V. A Complex hybrid System

We are developing a rear vehicle recognition system based on video that requires a real-time detecting (33frame/s) and the detection should be robust for different situations, for example, day and night, sunlight and rain, etc. A part of our system has been show in Fig 3.

We use knowledge-based methods for hypothesis generating and statistic methods for hypothesis verifying, it is an example of CHAIN. And we use a knowledge-based classifier (KB Filter) as a coarse one and a SVM classifier as a fine one, it is an example of ITERATIVE. About parallel pattern we use SELECT-DO pattern, that is, we use a shadow-based segmentation method for day and a headlight-based segmentation method for night. Use of these hybrid patterns makes the system very robust and we obtain the high accuracy too. We have finished a sample of our system which can process a frame (720*480) at a 200ms peek-time (Celeron 2.4G, 512M), and the DR (Detection Rate) can reach 96.5% and FAR (False Detection Rate) is 3.85%. Our next goal is to develop a sample in SIMD system on which we expect to reach the real-time.

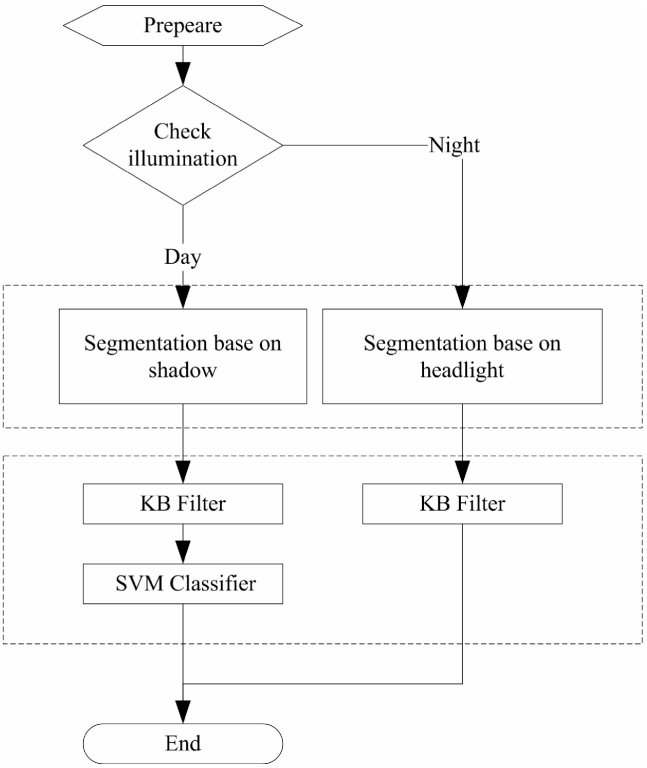

Fig. 3. A Part of the Complex Hybrid Architecture

VI. Conclusion

Hybrid methods can enhance the system's perception ability and make the system keep a robust and accurate detecting performance in different complex situations. To make hybrid methods more effective in image recognition, a research about hybrod approaches is very important.

This paper provides current basic patterns and gives analysis about their performance of real-time, accuracy and robustness. At the same time an analysis about expandability and flexibility of their software structure is given too. A sample shows that the system can obtain good expandability and flexibility when hybrid method brings accuracy and robustness. Moreover, real-time is respected.

Research about hybrid approaches can improve people's ability of constructing complex system, so it is necessary to enhance these researches. How to use these patterns to construct complex system is the goal of next step research.

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References

[1] G. Heidemann, F. Kummert, H. Ritter and G. Sagerer, "A Hybrid Object Recognition Architecture," in *1996 Proc. Int. Conf. Artificial Neural Networks*, pp. 305-310.

[2] R. Y.-M. Teo and R. Shinghal, "A Hybrid Classifier for Recognizing Handwritten Numerals," in *Proc. 4th Int. Conf. Document Analysis and Recognition*, 1997, pp 283-287.

[3] X. Pan, X. Z. Ye and S. Y. Zhang, "A Hybrid Method for Robust Car Plate Character Recognition", in *IEEE Int. Conf. Systems, Man and Cybernetics*, 2004, vol.5, pp 4733- 4737.

[4] M. G. Liu, J. Jiang and C. H. Hou, "Hybrid Image Segmentation Using Watersheds and Adaptive Region Growing," in *Int. Conf. Visual Information Engineering,* 2003, pp. 282- 285.

[5] Y. H. Tay, M. Khalid, R Yusof and C. Viard-Gaudin, "Offline Cursive Handwriting Recognition System based on Hybrid Markov Pattern and Neural Networks," in *2003 IEEE Proc. Int. Symposium Computational Intelligence in Robotics and Automation*, July 2003, vol.3, pp. 1190–1195.

[6] P. Zhang, L. H. Chen and A. C. Kot, "A Novel Hybrid Classifier for Recognition of Handwritten Numerals," in *IEEE Int. Conf. Systems, Man and Cybernetics*, 2004, vol.4, pp 2709-2714.

[7] X. Cao, R. Balakrishnan, "Evaluation of an On-line Adaptive Gesture Interface with Command Prediction," in *Proc. Graphics Interface Conf.*, 2005, pp. 187-194.

[8] L. Teng and L. W. Jin, "Hybrid Recognition for One Stroke Style Cursive Handwriting Characters," in *Proc. Eighth Int. Conf. Document Analysis and Recognition*, 2005, pp 232-236.

[9] A. L. Koerich, Y. Leydier, R. Sabourin and C. Y. Suen, "A Hybrid Large Vocabulary Handwritten Word Recognition System using Neural Networks with Hidden Markov Patterns," in *Proc. Eighth International Workshop on Frontiers in Handwriting Recognition*, 2002, pp 99.

[10] N. S. V. Rao and C. W. Glover, "Hybrid Intelligent Perception System," in *1991 IEEE Proc. Southeastcon*, vol.2, pp. 832-836.

[11] S. Gutta, J. Huang, I. F. Imam and H. Wechsler, "Face and Hand Gesture Recognition Using Hybrid Classifiers," in *Proc.* 2nd *Int. Conf. Automatic Face and Gesture Recognition*, 1996, pp 164.

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