Parallel Map Recognition Based on Multi-Layer Partitioned Blackboard Model

Tohru Oshitani and Toyohide Watanabe
Department of Information Engineering,
Graduate School of Engineering, Nagoya University
Furo-cho, Chikusa-ku, Nagoya 464-8603, JAPAN
{oshitani,watanabe}@watanabe.nuie.nagoya-u.ac.jp

Abstract

This paper addresses a parallel recognition paradigm to extract road information from urban map images. The main objective is to make clear the applicability between data parallelization and function parallelization in the road extraction process. We introduce the multi-layer partitioned blackboard model. This model manages relationships among the corresponding partitioned segments in different layers of blackboard so as to perform easily the cooperation among different processing procedures. Namely, individually partitioned segments in each layer are applicable to implement the data parallelization, while the relationships between corresponding partitioned segments in different layers support the cooperative control mechanism of function parallelization effectually.

1. Introduction

The adaptation of parallel processing techniques for image processing or pattern recognition is one of interesting issues to obtain the high performance processing. In particular, the parallelizing techniques are powerful for pixel-specific image processing procedures, and many methods have been developed on parallel computers [1, 2]. These methods were based on the paradigm of data parallelization, which applies the same procedures to the same type of data fragments.

On the other hand, the function parallelization on which different types of procedures work cooperatively or integratedly was proposed recently with respect to the cooperative processing paradigm: the blackboard-model-based methods [3], and multi-agent-oriented approaches [4] are typical. These traditional methods/approaches for image processing or pattern recognition did not always sufficiently address the total framework for recognizing characteristic objects and relationships among objects globally, except HEARSAY-II and a few projects.

This paper addresses an experimental parallel system for extracting road information from urban map images based on multi-layer partitioned blackboard model. This model is an enhanced version of conventional blackboard model in order to implement the data parallelization and function parallelization effectually. In this paper, the architectural framework for road extraction is first presented from a viewpoint of the parallelization paradigm. Then, the control mechanism among processing procedures is discussed with respect to the reference/access of data on multi-layer partitioned blackboard. Additionally, the performance of prototype system is evaluated through some experimental results.

2. Framework

The multi-layer partitioned blackboard model is illustrated in Figure 1. Each layer in our blackboard holds individual processing data, adaptable to the corresponding processing procedures: each processing procedure transforms the data in the lower layer into data in the upper layer. Also, each layer in blackboard is partitioned into the same segment sizes through layers and these segments are uniformly correspond among layers.

The road extraction process is composed of individual different processing procedures [5], as shown in Figure 2. These procedures consume the data generated by the previous procedure and produce new data for the next procedures stepwisely.

In our multi-layer partitioned blackboard, the data parallelization is applicable to the execution of processing procedures on individually partitioned segments of each layer, and the function paralleliza-

1051-4651/98 $10.00 © 1998 IEEE

is performed cooperatively among different processing procedures in the different layers.

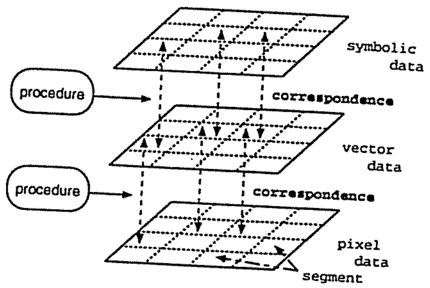

Figure 1: Multi-layer partitioned blackboard model

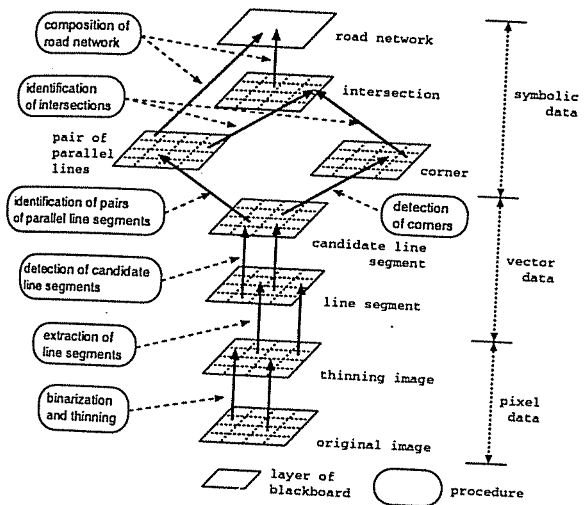

Figure 2: Road extraction in multi-layer partitioned blackboard

3. Road Extraction System

Road extraction system consists of multi-layer partitioned blackboard, control mechanism and processor as shown in Figure 3.

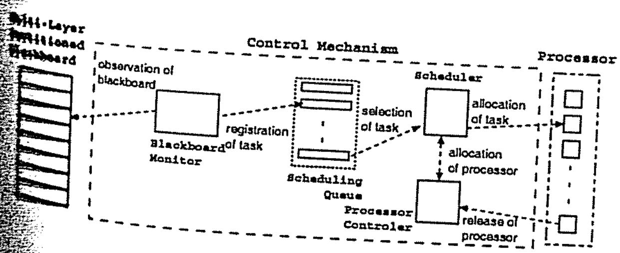

Figure 3: System configuration

3.1. Multi-layer partitioned blackboard

In the road extraction process, the data forms are changed according to the processing phases: pixel to vector, and vector to symbol, as shown in Figure 2.

It is important to keep the correspondences among these different data forms from a viewpoint of processing efficiency. In Figure 4, the correspondences among segments in different layers are illustrated. Namely, the data in each segment are specified as characteristic points and held in the segment according to their characteristic points. And, the segments of one layer are corresponded to the segments of another layer by one-to-one.

Under the correspondences among segments in different layers, the access control mechanism makes parallel computation of high performance possible. When the data which are newly generated by a processing procedure in the lower layer are written into the upper layer, they are checked whether they have already been existing or related to the existing data in the segment according to their characteristic points. If the data are neither existing nor related to, the newly generated data are written practically.

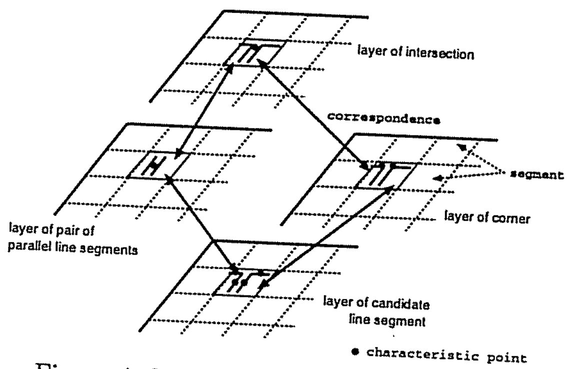

Figure 4: Management of blackboard data

3.2. Control mechanism

Control mechanism is composed of blackboard monitor, scheduling queue, scheduler and processor controler, as shown in Figure 3, and manages the effectual execution control among processing procedures.

The blackboard monitor watches the blackboard. When some changes were occurred on the blackboard, the blackboard monitor generates some tasks related to the changes. The task consists of pointers to notable data and the processing procedure. After having generated tasks, the blackboard monitor registers them into the scheduling queue. This scheduling queue is independently prepared every layer of blackboard, so that tasks are registered into the queue associated with the layer on which changes occurred.

The scheduler plays a role of selecting an appropriate task based on the queue priority and the number of tasks held in the scheduling queue. The processing procedure reads the data from segments in the lower layer, and writes the generated data into the corresponding segments in the upper layer. Thus, the task priority of scheduling queue associated with the lower layer is larger than that in the upper layer.

The processor controler manages the state of processors, which is set as "idle" or "busy". When the scheduler sends a request of processor allocation, the processor controler selects one from "idle" processors.

4. Experiment

We implemented a prototype system of road extraction on the parallel computer with distributed memory AP1000, produced by Fujitsu Ltd. Co.. AP1000 consists of one host computer and 16 cell computers. In our system, one cell computer is assigned to implement the multi-layer partitioned blackboard and all rest cell computers execute tasks as processors. While, the host computer takes roles of control mechanism.

In this experiment we used 1/10,000 urban maps, which were digitalized by the image scanner with 400 dpi and 256 gray levels, in Figure 5. Figure 6 shows a road network composed by our prototype system.

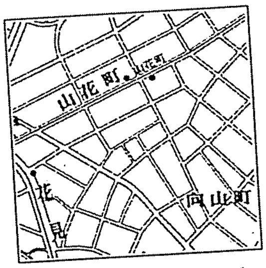

Figure 5: An urban map

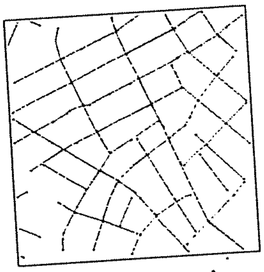

Figure 6: Road network

We compared the processing performance between parallel processing and sequential processing using four kinds of urban maps. Sequential processing was proposed in [5], and executed on workstation Sun Sparcstation S-4/1. Table 1 shows the execution times. The numerical data in the first two columns indicate the execution times and one in the last column indicates the parallelization ratios. In order to evaluate relatively the processing ability of AP1000 and that of S-4/1, we calculated a product of two 300 × 300 arrays. Table 2 shows the recognition ratios. The numerical data in each field indicate the numbers of observed/extracted road fragments and ones in each parenthesis field indicate the recognition ratios. From the results in Tables 1 and 2, it is clear that we obtained the reasonable performance and good recognition ratio. There are slightly differences between parallel processing and sequential processing in the recognition ratio. This is because each segment in our parallel approach is processed locally and independently.

Table 1: Execution time (by second)

	Sequential(A)	Parallel(B)	A/B
MAP1	230.51 sec.	24.77 sec.	9.31
MAP2	169.52 sec.	15.06 sec.	11.26
MAP3	184.96 sec.	18.40 sec.	10.05
MAP4	178.07 sec.	16.45 sec.	10.82
Product	142.11 sec.	11.81 sec.	12.03

Table 2: Recognition ratio

	Source	Sequential	Parallel
MAP1	199	172 (86.4%)	166 (83.4%)
MAP2	129	95 (73.6%)	104 (80.6%)
MAP3	226	198 (87.6%)	181 (80.0%)
MAP4	162	115 (71.0%)	113 (69.8%)

5. Conclusion

In this paper, the parallel extraction of road information from urban map images was discussed. In order to execute various processing procedures in data parallelization and function parallelization, the control mechanism among processing procedures was implemented, using the multi-layer partitioned blackboard.

However, currently the recognition ratio and processing time are not always sufficient for our final goal. As for the improvement of recognition ratio, we must introduce the backward control in addition to this forward control among different layers. And, as for the improvement of processing time, we should enhance the task scheduling control mechanism and develop parallelizing-oriented procedures.

References

[1] Y.Y.Zhang and P.S.P.Wang: "Analysis and Design of Parallel Thinning Algorithms - A Generic Approach", *Int'l Jour. of Pattern Recognition and Artificial Intelligence*, Vol. 9, No. 5, pp. [illegible] (1995).

[2] R.Nevatia and C.C.Reinhart: "Parallel Processing for Spatial Grouping and Matching", *Proc. of 12th ICPR*, Vol. III, pp. 290–294 (1994).

[3] A.Barr, P.R.Cohen and E.A.Feigenbaum: *Handbook of Artificial Intelligence*, Vol. [illegible], Addison-Wesley Pub. Co. (1989).

[4] T.Matsuyama and T.Wada: "Cooperative [illegible] Reasoning for Image Understanding", *Int'l [illegible] PR&AI*, Vol. 11, No. 1, pp. 205–227 (1997).

[5] T.Hayakawa, T.Watanabe, [illegible] and K.Kawaguchi: "Recognition of Roads [illegible] ban Map by Using the Topological Road [illegible]" *Proc. of MVA'90*, pp. 215–218 (1990).