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Cost effective mixed-type value predictor using distributed classification method

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Abstract

We have investigated the conventional mixed-type value predictors, pointing out their limitations due to the inefficient use of data table entries. To improve the cost effectiveness of the conventional mixed-type value predictors in terms of the performance/cost ratio, we propose a new mixed-type value predictor, which uses the *distributed classification method*. The proposed value predictor has no centralized classification tables, but it uses *distributed and local classification tables* for each subsidiary predictor to classify instructions, to update data tables, and to predict result values. Static analysis of the cost reveals that the proposed value predictor decreases the cost by 30 and 10% compared with two conventional predictors, respectively. As well, the proposed value predictor increases the performance by 1% in terms of IPC, and, finally, improves the performance/cost ratio by 40 and 10% compared with two conventional methods.

Keywords: Value predictor; Instruction-level parallelism; Cost reduction; Performance evaluation; Microarchitecture

1. Introduction

Numerous methods have been proposed to improve the instruction-level parallelism. Until a few years ago, however, data dependency relations among instructions have been considered as the fundamental limitation of the performance improvement [1]. Fortunately, value prediction methods have been proposed recently to overcome the limitation of performance improvement [2–8]. A value predictor predicts results of instructions before executions and forwards prediction values to dependent instructions as input values. As a result, two instructions having data dependency relation in a program can be executed simultaneously, and the overall performance is improved.

Several value predictors have been proposed to date. Conventional value predictors can be categorized into two types: the uni-type predictor having only one subsidiary predictor [2,6–8] and the mixed-type predictor having multiple subsidiary predictors [4,5]. Last [2,6], stride [2,6], two-level [7], and hybrid [8] predictors are classified into the uni-type predictor. On the other hand, CDCCT (Centralized and Dynamic Classification with Classification Table) [4] and CDCST (Centralized and Dynamic Classification with Stride Table) [5] are classified into the mixed-type predictor. The mixed-type value predictors usually show higher performance improvement than uni-type predictors because the mixed-type value predictors find an appropriate subsidiary predictor dynamically for each instruction and for each execution interval of the instruction. From the viewpoint of cost overhead, however, since several subsidiary predictors as well as a classification table are used, the mixed-type value predictors have a higher cost overhead than uni-type predictors.

Meanwhile, most value predictors have much more expensive cost overhead than other high performance design methods such as data cache, instruction cache, and branch predictors. The previous paper of value predictor [2] mentioned that new cost reduction methods are required because the cost overhead of the value predictor is still high, although the value predictor shows higher performance improvement than data cache with the same cost. In addition,

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power consumption, one of the most important design constraints in the current processor design, increases with the cost of value predictor. Consequently, a more cost effective value predictor is required, which has a lower cost overhead and power consumption with a less performance degradation.

Not only to reduce the above-mentioned negative effects such as high area overhead and additional power consumption, but also to increase performance improvement ratio of value predictors, a new cost effective mixed-type value predictor, mainly in terms of performance/cost ratio, is proposed. In this research, only the mixed-type value predictors are taken into account since the uni-type value predictors show slightly higher performance improvement, and especially since several cost reduction methods for the uni-type value predictors have already been proposed [9,10].

The preliminary analysis of the conventional mixed-type value predictors reveals that most of the data entries are not used for the prediction, and that the waste of data entries causes high cost overhead with little performance improvement. For effective use of the wasted data entries, the proposed cost effective mixed-type value predictor divides the original data tables into two parts: *local classification tables* and *data tables* for each subsidiary predictor. As a result, the new mixed-type value predictor, which uses the *distributed classification method*, has no centralized classification table and makes simpler data tables. Thus, the overall cost is reduced, and yet the performance improvement ratio is the same or even higher. Static analysis shows that the newly proposed mixed-type value predictor decreases the area cost by 30 and 10% compared with CDCCT and CDCST, respectively. Also the proposed value predictor increases the performance by 1%, and, finally, improves the performance/cost ratio by 40 and 10% compared with CDCCT and CDCST, respectively. In Section 2, the conventional mixed-type value predictors and their drawbacks are explained. The newly proposed mixed-type predictor is shown in Section 3. Analyses of the cost and the performance of the proposed mixed-type predictor are discussed in Section 4. Finally, the higher cost effectiveness of the proposed mixed-type value predictor is summarized in Section 5.

2. Related work and analysis

Usually mixed-type value predictors have three subsidiary predictors: the *last*, *stride*, and *two-level* predictors. A mixed-type value predictor dynamically classifies instructions in order to select an appropriate subsidiary predictor. The two mixed-type value predictors that have been proposed to date are: CDCCT (Centralized and Dynamic Classification with Classification Table) and CDCST (Centralized and Dynamic Classification with Stride Table).

2.1. CDCCT

A centralized classification table is used for dynamic classification in CDCCT [4] Fig. 1 shows a simple hardware scheme of CDCCT. The *classification table* is used to classify instructions and has two result values: *old value1* and *old value2* for each instruction. It classifies an instruction when three consecutive result values are generated such as *old value1* and *old value2*, and the recently generated result value. If three consecutive result values have a same value, the instruction is classified to be predictable by the *last* predictor, and the prediction information of the instruction is stored in the data table of the *last* predictor. If two stride values of three result values are the same, the instruction is considered predictable by the *stride* predictor. Otherwise, prediction information of the instruction is stored in the *two-level* predictor. To select an appropriate subsidiary predictor in the prediction phase,

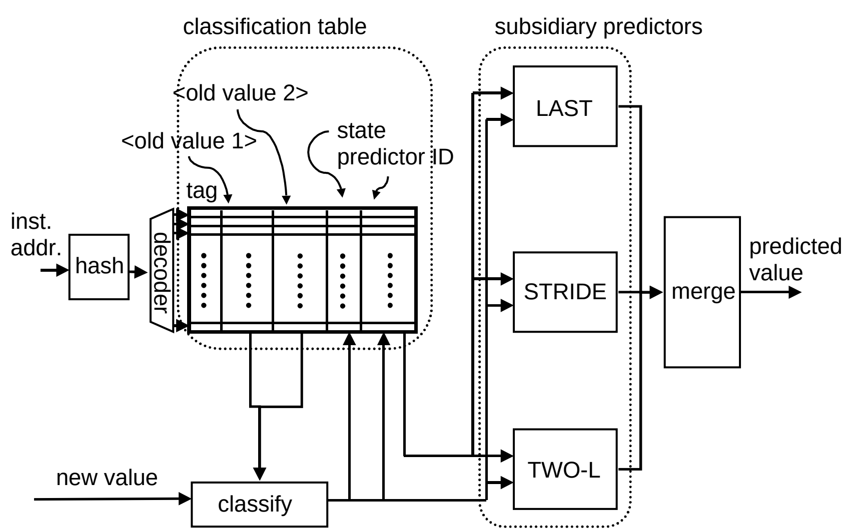

Fig. 1. CDCCT.