EVM's Java Dynamic Memory Manager and Garbage Collector

Sang-Yun Lee¹ and Byung-Uk Choi²

¹Dept. of Electronical Telecommunication Engineering, Hanyang University, Seoul, Korea
sylllee@etri.re.kr

²Division of Information and Communications, Hanyang University, Seoul, Korea
buchoi@hanyang.ac.kr

Abstract. In this paper, we propose the dynamic memory manager and garbage collector for the embedded Java virtual machine. In order to facilitate to memory allocation and deallocation fast, the memory manager divides a heap into various sizes and thus manages it with the unit of block which is a set of identical cell. And we propose a new 4-color based Mark & Sweep garbage collector in order to support a multi-thread.

Keywords: Garbage Collector, Memory Management, Mark & Sweep, EVM.

1 Introduction

We have developed the *Embedded Java Virtual Machine* (EVM), in which we introduce the dynamic memory manager and the garbage collector implemented in the EVM. The proposed memory manager divides the memory into a block and a cell. The cell is a constant sized-memory and thus becomes the unit of the object allocation and garbage collection. A block manages the cells with identical size through a linked-list. Dividing the memory into a block and a cell facilitate allocation of memory fast, because it quickly finds out the cell that fits the size of required object.

The proposed garbage collector is based on 3-color Mark & Sweep collector [1]. This garbage collector operates well without any problem in a single thread. However, in the Java program operating in a multi-thread, there is a problem that the object is collected as garbage, when a garbage collector operates before the object allocated in the other thread is defined as a root set. In this paper, we propose the 4-color Mark & Sweep garbage collector in order to solve this problem.

2 Design of Dynamic Memory Manager and Garbage Collector

We designed the memory structure considering the following criteria. Firstly, the memory allocation and deallocation speed must be fast. Secondly, we must consider that the programs operating in an embedded system normally operates with small sized objects. Thirdly, the large object must be handled with special care. Fourthly, the memory fragmentation must be small. Lastly, the expansion of memory capacity must be possible.

We adopted a free-list [2] to satisfy them. Fig. 1 shows the memory block structure designed with the free-list.

Fig. 1. The memory architecture

The memory area is divided into the system management memory region and the VM management memory region; the former obtains the whole heap from the system and stores the objects for controlling the latter and the latter allocates or deallocates an object dynamically in a virtual machine. And the latter is further divided into a block header and a block body. In the block header, the pointer of the block information structure, the color information of cells belonging to the block, and type information of memory allocation are stored.

The number of blocks is determined by the initial heap size assigned when the Java virtual machine is initiated. And the block memory is created during the Java virtual machine's initialization. The memory is additionally allocated from the system if the requested memory allocation exceeds the maximum heap size.

The Memory Map has three types. The *AvailableBlock* is the block with an available cell. The *EmptyBlock* is the place where all cells are deallocated by the garbage collector. *FilledBlock* is the block with no more available cells. Firstly, the available block is searched in the *AvailableBlock*, and the cell to be allocated is then appointed. If it is unable to find the cell in the *AvailableBlock*, new cell is allocated in the *EmptyBlock*. A new block and a new cell are created if it is unable to more allocate in the *EmptyBlock*. Specially, when there is request for allocation greater than 4,040 bytes it is allocated in the *EmptyBlock*.

The proposed garbage collector is based on the 3-color garbage collector that is easy to implement and its overhead is low in comparison with the other algorithm. The 3-color based *Mark & Sweep* garbage collector runs normally in the single threaded environment, however it can cause serious problems in the multi-threaded environment [3,4].

Fig. 2. The Problem of 3-color based Mark & Sweep Garbage Collector

Fig. 2 is an example of programs in which the Java application runs two threads at the same time. The source code of the thread #1 and thread #2 is the internal implementation code of the Java virtual machine. In the thread #1, the objects were stored within an obj1 and an obj2. The obj1 was stored in the Java stack by performing the PUSH OBJECT() function.

By the way, assume that the thread #1 was stopped due to the thread #2’s calling the garbage collector, before an obj2 was stored in the Java stack. As shown in the Java stack memory structure, an obj2 was allocated from the memory manager but it is in the state of not going over to the Java stack. Therefore, the garbage collector determines the obj2 as garbage and collects it. Consequently, when the garbage collection is finished, thread #1 runs again the obj2 cannot actually indicate the memory address value.

We propose the 4-color based *Mark & Sweep* garbage collector to solve this problem. The proposed garbage collector has additional color more called *YELLOW* besides 3 colors used in 3-color based *Mark & Sweep* garbage collector. The object with *YELLOW* color represents that it is not yet included in the root set but it is excluded from target object during the garbage collection. When an object is created, the object does not have the *WHITE* color but the *YELLOW* color. And it is changed to the *WHITE* color on appropriate time. We managed the memory for the *YELLOW* color object specially.

3 Experimental Result

We measured how the memory fragmentation changed as the number of object increased. We classified the objects into three classes for an experiment. In group A, we continuously created array of integer of which size is 10. In group B, we continuously created array of double continuously of which size is 10. In group C, we continuously created array of integer, double, and float of which size is 10. Fig. 3 shows the experimental result.

Fig. 3. Fragmentation variation according to creation of object

As shown in Fig. 3, we can know that although the number of objects created increases the memory fragmentation ratio is steadily maintained.

4 Conclusion

In this paper, we proposed the memory manager and garbage collector of the EVM, an embedded Java virtual machine. The memory manager adopted the free-list. This method has the disadvantage of the memory fragmentation but the memory allocation is fast. We designed the memory manage with blocks and cells efficiently. So, the internal and external memory fragmentation was very low (within 10%).

We adopted 3-color based *Mark & Sweep* garbage collector, whereas we proposed 4-color based *Mark & Sweep* garbage collector to support a multi-threaded environment.

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