A Method of Memory Reduction for Specific Object Recognition with a Bloomier Filter

Katsufumi Inoue*, Koichi Kise*

* Graduate School of Engineering, Osaka Prefecture University, Japan
E-mail: inoue@m.cs.osakafu-u.ac.jp, kise@cs.osakafu-u.ac.jp

Abstract

Specific object recognition based on nearest neighbor search of feature vectors requires a huge amount of memory to store all feature vectors for distance calculation. To solve this problem, we propose a memory reduction method for specific object recognition with no distance calculation for matching feature vectors. The proposed method is characterized by the use of a Bloomier filter, which is far memory efficient than a hash table, for the storage of feature vectors. The proposed method is evaluated based on experiments of planar and 3D specific object recognition in comparison to a method with a hash table.

1. Introduction

Specific object recognition has been spotlighted as a key technology to deal with a large volume of image data effectively and efficiently. This paper focuses especially on the specific object recognition methods which employ local features such as SIFT (Scale-Invariant Feature Transform) [1].

A fundamental method of specific object recognition is based on voting by matching feature vectors [2]. This method employs nearest neighbor search of feature vectors for matching. Although even such a simple method offers high recognition rate, it poses the following problem caused by a large number of feature vectors: they need an immense amount of storage.

A possible approach to solve this problem is to recognize the objects without storing the feature vectors. This means that no distance calculation is employed for matching feature vectors. From this viewpoint, a hash-based method has been proposed [2]. In this method, only the existence of feature vectors is marked in the hash table, and matching of feature vectors is done by checking the mark. Since there is no feature vector stored in the database, a drastic reduction can be achieved. However, this method still has a problem about the amount of memory: most bins of the hash table are empty. Accordingly, there is still a room of improving the space efficiency of this method.

To achieve the breakthrough, we propose a new memory reduction method with a Bloomier filter [3]. The Bloomier filter is a probabilistic data structure that is more space efficient than the hash table. The Bloomier filter differs from the hash table in that the Bloomier filter allows false positives of feature vectors. The objective of this research is to reduce the amount of memory for object recognition by using the Bloomier filter, while keeping the recognition rate as high as possible. In this paper, the proposed method is evaluated based on experiments of planar and 3D specific object recognition in comparison to a method with a hash table.

2. Bloom and Bloomier filters

In this section, we explain the Bloomier filter [3] and the Bloom filter [4] which is a base of the Bloomier filter.

The Bloom filter is a space efficient probabilistic data structure. This is used to memorize whether an element is a member of a data set. The Bloom filter has a risk of false positives which are a type of error that an element is erroneously recognized as a member of a data set. We utilize the space efficiency of Bloom filters in order to reduce the amount of memory for storing feature vectors.

The Bloomier filter is an associative array which can associate a value with a feature vector by using multiple Bloom filters. We utilize the Bloomier filter to associate the object IDs. Suppose an object ID is represented by n bits, we prepare the Bloomier filter consisting of $2n$ Bloom filters. In other words, we distinguish 2^n objects with the above Bloomier filter.

3. Proposed Method

In this section, we propose a specific object recognition method using the Bloomire filter. The proposed method is based on the voting strategy. We utilize feature vectors calculated by PCA-SIFT [5].

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Figure 1: Examples of 55 3D objects.

Figure 2: Examples of 10,000 planar objects.

3.1 Database Construction

Let $B_1^{(0)}, B_2^{(0)}, \cdots, B_n^{(0)}$ be the Bloom filters whose associated value is 0 and $B_1^{(1)}, B_2^{(1)}, \cdots, B_n^{(1)}$ be those whose associated value is 1. Then the feature vectors are stored to n Bloom filters in order to associate the object ID.

3.2 Object Recognition

The recognition process with the Bloomier filter is as follows. First, in order to decide whether the ith bit $(i = 1,2,\cdots,n)$ of object ID is 0 or 1, both Bloom filters $B_i^{(0)}$ and $B_i^{(1)}$ are applied to a query feature vector $\boldsymbol{q}$. If $B_i^{(0)}$ contains $\boldsymbol{q}$, the ith bit of object ID is 0. On the other hand, if $\boldsymbol{q}$ is contained in $B_i^{(1)}$, the ith bit of object ID is 1. After this process is applied to all bits of object ID, we can obtain the object ID for voting. Finally, the object having the maximum number of votes is the result of recognition.

4. Experiments

We have evaluated the proposed method using two dataset: 55 3D objects and 10,000 planar objects. The dataset of 55 3D objects was prepared by ourselves by taking images of 55 3D objects. **Figure 1** shows some examples. The images were captured by rotating each object on a turn table in increments of 5° from frontal view and the above diagonal 15º and 30º using the web camera. In these images, the images in increments of 10º (0 º,10 º,…,350 º) were utilized for database construction. The rest were utilized as query images. In total 1.2 million feature vectors were extracted from images for database construction. In addition, we utilized 10,000 objects used in [2]. The total number of feature vectors was 20 million. Some examples are shown in **Figure 2**.The proposed method was compared to the conventional method proposed in [2].

Table 1: Experimental result for 55 3D objects.

	Accuracy[%]	Memory[MB]
Proposed	99.75	73
Conventional	99.75	2199

Table 2: Experimental result for 10,000 planar objects.

	Accuracy[%]	Memory[MB]
Proposed	94.25	340
Conventional	95.35	2741

Tables 1 and **2** show the experimental results. From experimental result of 55 3D objects and 10,000 planar objects, we have achieved smaller required memory using the proposed method if the similar recognition rates were obtained.

5. Conclusion

In this paper, we have proposed a new memory reduction method for specific object recognition by using the Bloomier filter. Future work is to evaluate the proposed method with more objects.

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6. References

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