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Uncertainty-Based Active Learning via Sparse Modeling for Image Classification

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OUTLINE

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2. Uncertainty Evaluation
3. Sparse Modeling
4. Experiment

Introduction

- Batch mode active learning
- Multi class classification
- Consider uncertainty and diversity of examples
- Diversity is evaluated by sparse representation
- Select examples by solving a QP problem

Uncertainty Evaluation

Classification Model: "one vs. the rest" SVM

The uncertainty score based on the "**best vs. the second best**" (BvSB) strategy

$$s_{\mathrm{BvSB}}(x_i) = \max(\widehat{w}_{k_2}^T x_i - \widehat{w}_{k_1}^T x_i + 1, 0),$$

where k1 and k2 are the first two most likely predicted classes.
The authors take max(·) operation to restrict the uncertainty score in the range of [0, 1].

Sparse Modeling

Scores of unlabeled data

Similarity matrix among all the unlabeled samples

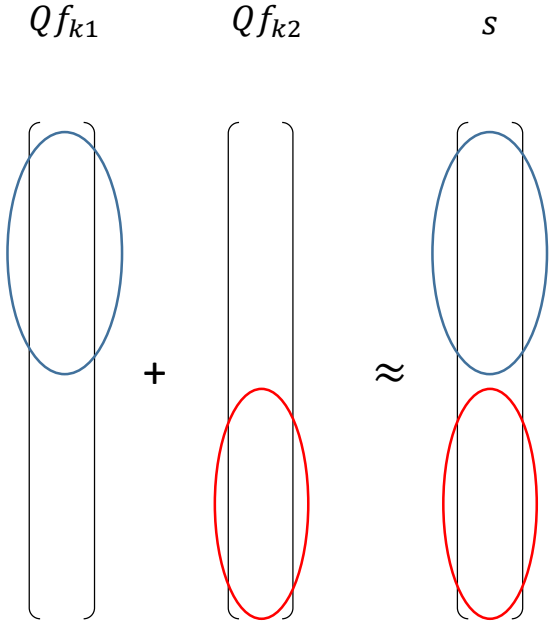
Uncertainty score

$$\widehat{f} = \arg\min_{f} \ \|Qf - s\|^2,$$

$$s.t. \ \|f\|_0 = B_q, \quad \mathbf{0} \leq f \leq \mathbf{1},$$

Batch size

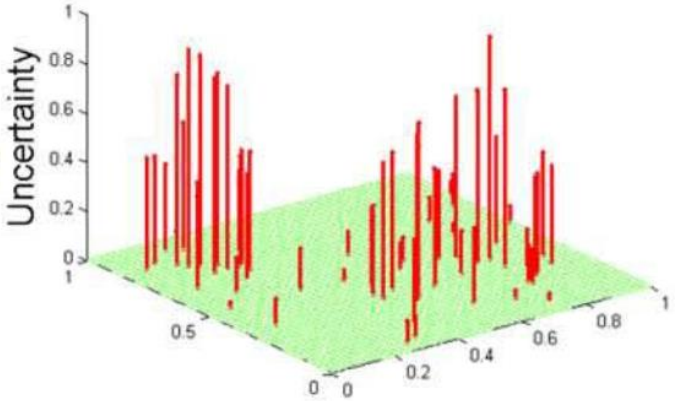
Sparse Modeling



选中的样本1与所有未标记样本的相似度向量

选中的样本2与所有未标记样本的相似度向量

未标记样本的不确定度向量



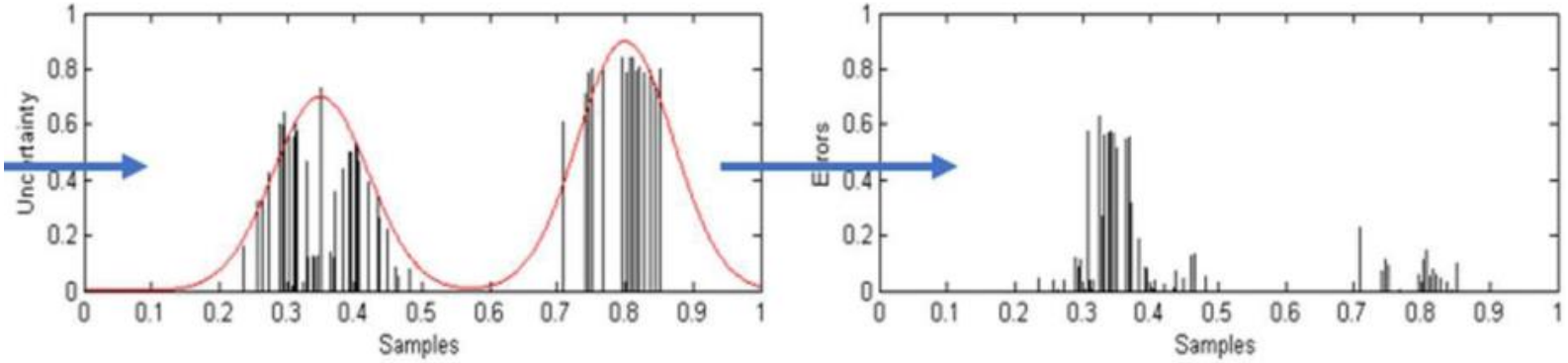
$$Q_{i,j} = \begin{cases} \exp\left(-\frac{\|\tilde{x}_i - \tilde{x}_j\|^2}{\sigma^2}\right), & \text{if } i \in N_j, \\ 0, & \text{if } i \notin N_j, \end{cases}$$

$$\tilde{x} = [\widehat{w}_1, \widehat{w}_2, \ldots, \widehat{w}_K]^T x,$$

Sparse Modeling

Problem

- Sparse modeling is sensitive to the samples with low uncertainty scores. the samples with high uncertainty cannot be well represented by the kernel if several low uncertainty samples are around

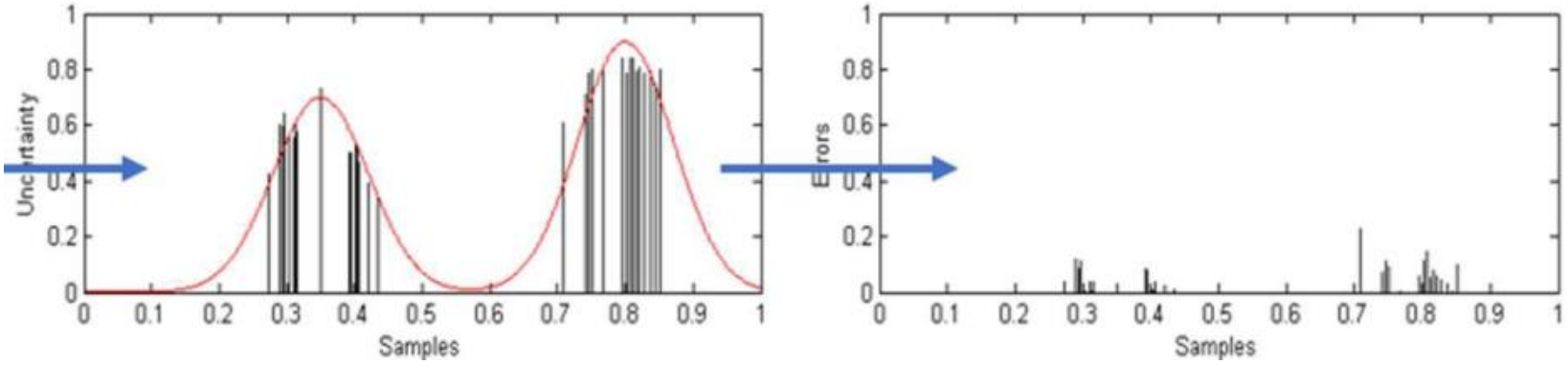


Sparse Modeling

Solution

- Filter out low uncertainty samples before sparse modeling.

✓ Reduce the re-construction error
✓ Reduce the size of selection pool



Optimization

$$\begin{aligned}\widehat{f} &= \arg\min_f \ \frac{1}{2} f^T Q^T Q f - \lambda_1 f^T Q^T s - \lambda_2 f^T s, \\ &= \arg\min_f \ \frac{1}{2} f^T Q^T Q f - f^T (\lambda_1 Q^T + \lambda_2 I) s, \\ &\quad s.t. \ \ \| f \|_0 = B_q, \quad \mathbf{0} \le f \le \mathbf{1}.\end{aligned}$$

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QP Problem !

$$\begin{aligned}\widehat{f} &= \arg\min_f \ \| Qf - s \|^2, \\ &= \arg\min_f \ \frac{1}{2} f^T Q^T Q f - f^T Q^T s \\ &\quad s.t. \ \ \| f \|_0 = B_q, \quad \mathbf{0} \le f \le \mathbf{1}.\end{aligned}$$

Experiment

TABLE I

DATASET DESCRIPTION

Name	# of samples	# of class
COIL-20	1440	20
MNIST (subset)	3000	10
Cam-Trawl Fish	1026	5
Chute Fish	5032	27

TABLE II

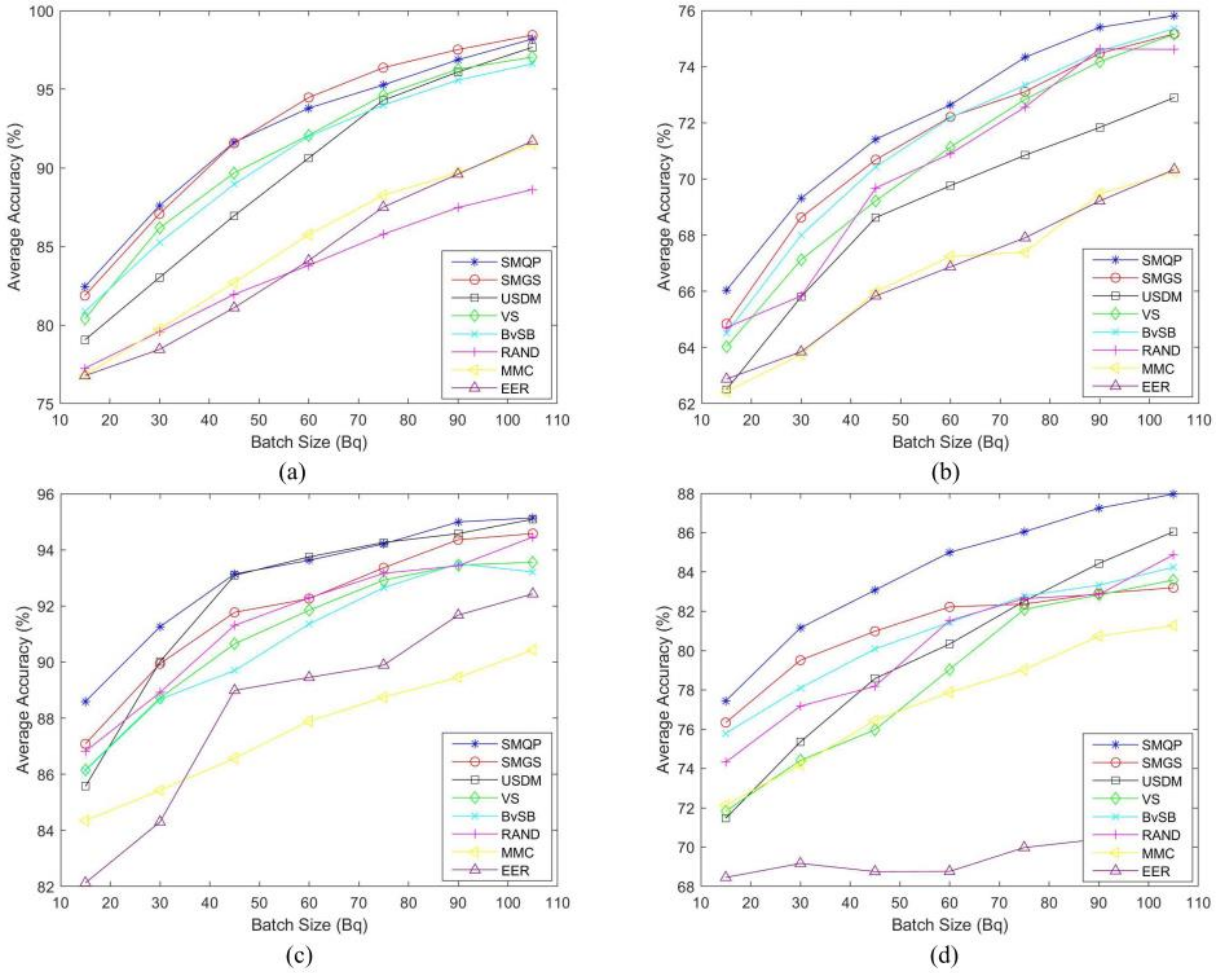
FEATURE DESCRIPTION

Name	Feature size
COIL-20 (concat)	1024
COIL-20 (CNN)	1536
MNIST (concat)	784
MNIST (CNN)	1024
Cam-Trawl Fish (BoF)	7168
Cam-Trawl Fish (CNN)	1536
Chute Fish (BoF)	7168
Chute Fish (CNN)	1536

Compared methods:

- **BvSB**
- **EER**
- **Random**
- **VS** [ICML'03] which incorporates diversity for a query via version space reduction
- **USDM** [IJCV'15], which is uncertainty sampling based active learning with diversity maximization
- **MMC** , which is active learning with maximum model change
- **SMQP**
- **SMGS**

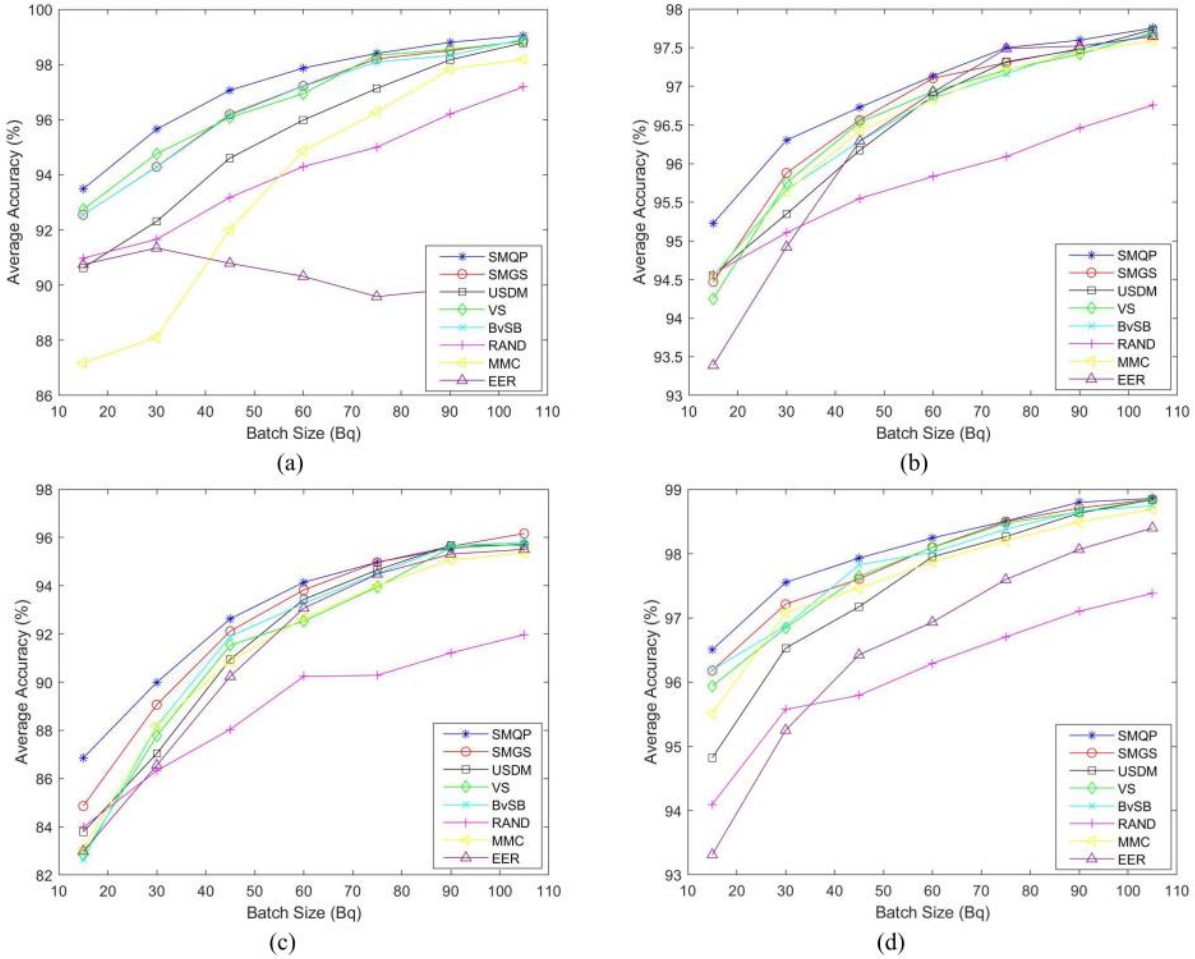
Experiment



Average accuracy with seed size ***c* = 3** on four datasets **using traditional features**.

(a) COIL-20. (b) MNIST. (c) Cam-Trawl Fish. (d) Chute Fish

Experiment



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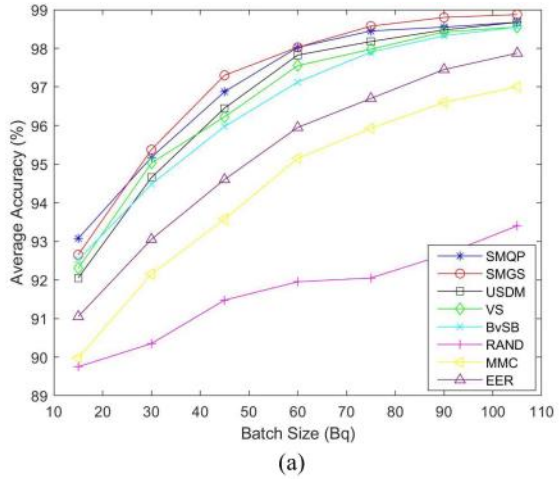
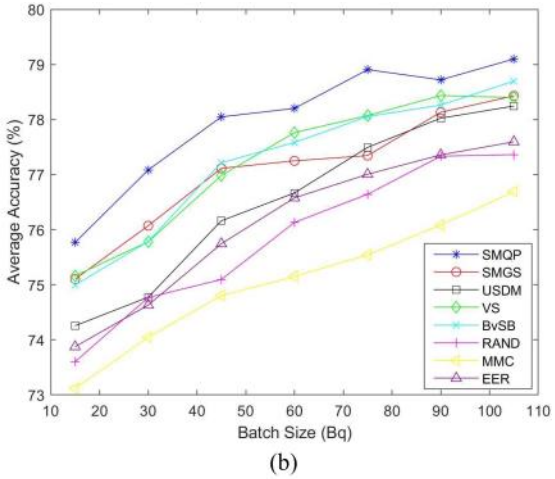
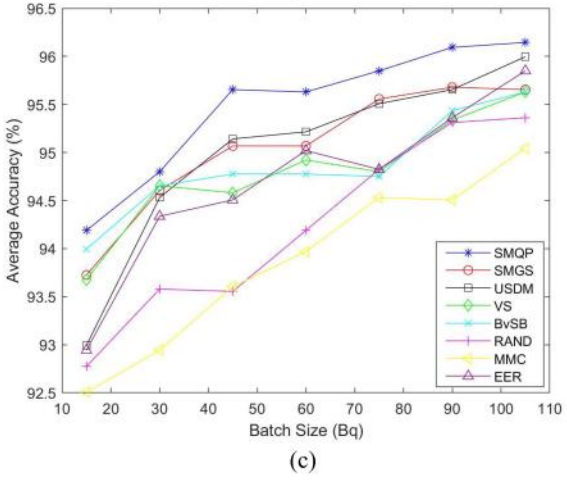


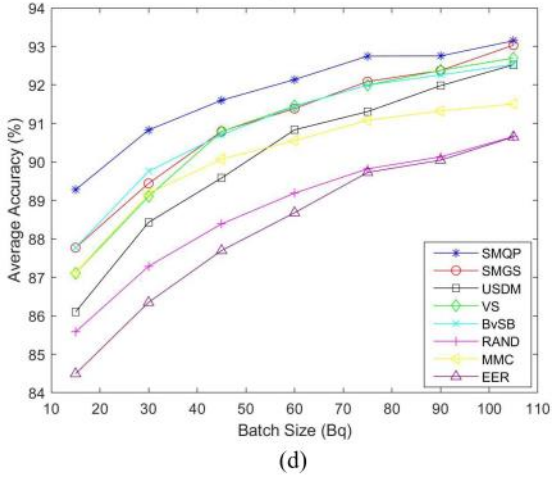
(a)



(b)



(c)

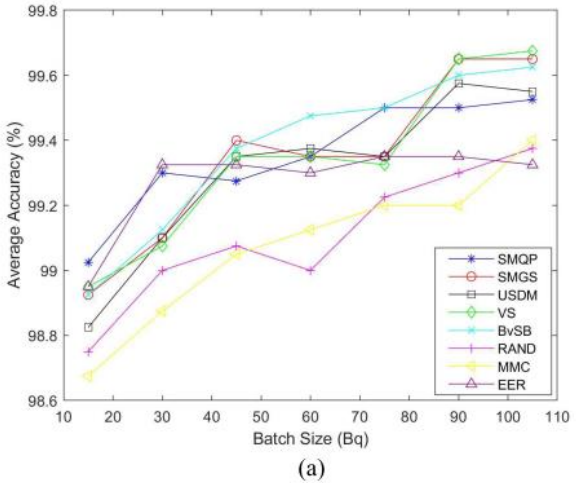


(d)

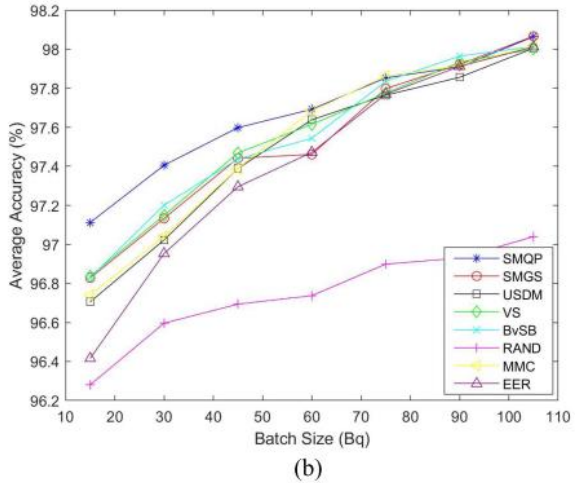
Average accuracy with seed size ***c* = 9** on four datasets **using traditional features**.

(a) COIL-20. (b) MNIST. (c) Cam-Trawl Fish. (d) Chute Fish

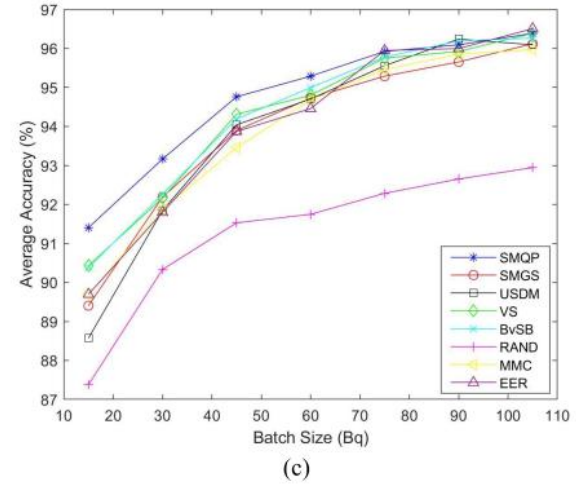
Experiment



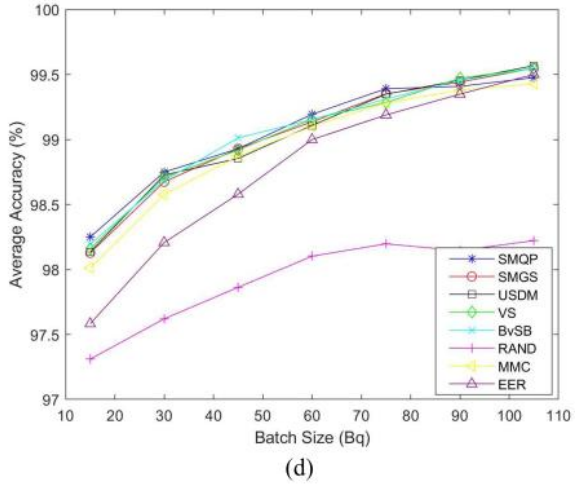
(a)



(b)



(c)



(d)

Average accuracy with seed size ***c* = 9** on four datasets **using CNN features**.

(a) COIL-20. (b) MNIST. (c) Cam-Trawl Fish. (d) Chute Fish

Experiment

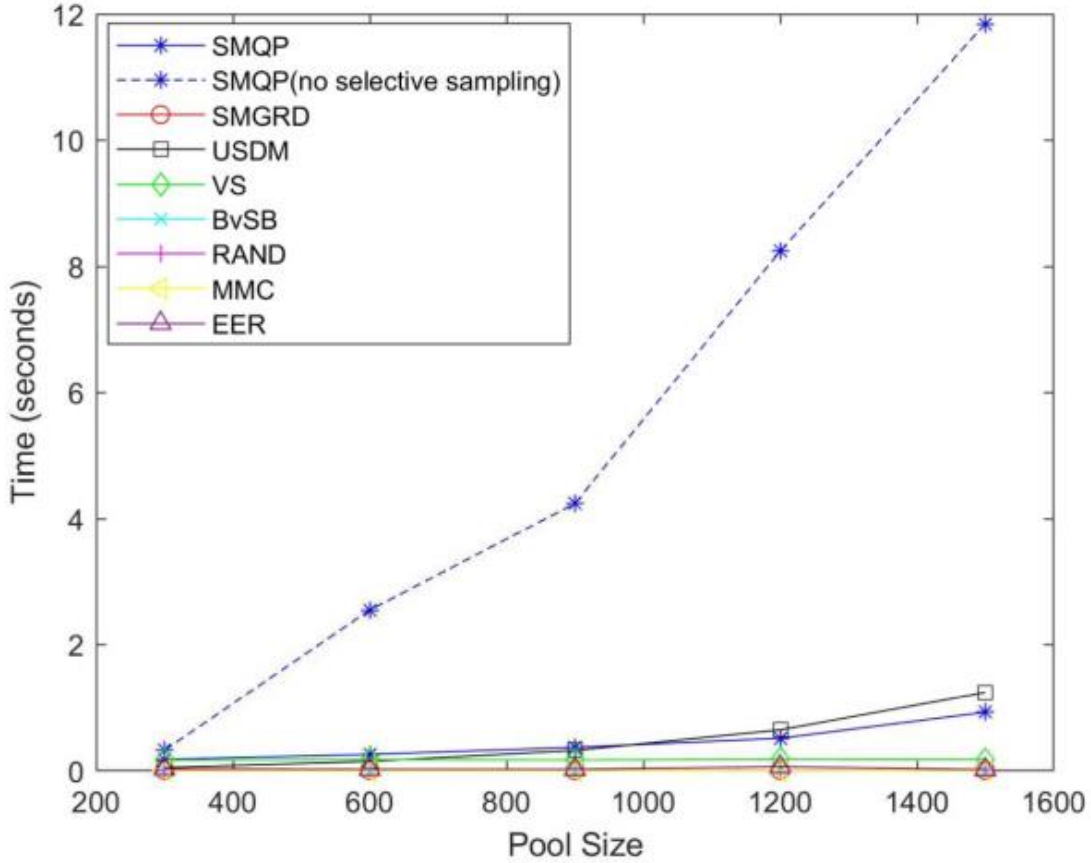


Fig. 10. The elapsed time comparison.