Combining a self-organising map with memory-based learning

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Abstract

Memory-based learning (MBL) has enjoyed considerable success in corpus-based natural language processing (NLP) tasks and is thus a reliable method of getting a high-level of performance when building corpus-based NLP systems. However there is a bottleneck in MBL whereby any novel testing item has to be compared against all the training items in memory base. For this reason there has been some interest in various forms of memory editing whereby some method of selecting a subset of the memory base is employed to reduce the number of comparisons. This paper investigates the use of a modified self-organising map (SOM) to select a subset of the memory items for comparison. This method involves reducing the number of comparisons to a value proportional to the square root of the number of training items. The method is tested on the identification of base noun-phrases in the Wall Street Journal corpus, using sections 15 to 18 for training and section 20 for testing.

1 Introduction

Currently, there is considerable interest in machine learning methods for corpus-based language learning. A promising technique here is memory-based learning[1] (MBL) (Daelemans et al., 1999a), where a task is redescribed as a classification problem. The classification is performed by matching an input item to the most similar of a set of training items and choosing the most frequent classification of the closest item(s). Similarity is computed using an explicit similarity metric.

MBL performs well by bringing all the training data to bear on the task. This is done at the cost, in the worst case, of comparing novel items to all of the training items to find the closest match. There is thus some interest in developing memory editing techniques to select a subset of the items for comparison.

This paper investigates whether a self-organising map (SOM) can be used to perform memory editing without reducing performance. The system is tested on base noun-phrase (NP) chunking using the Wall Street Journal corpus (Marcus et al., 1993).

2 The Self-Organising Map (SOM)

The SOM was developed originally by Kohonen (1990) and has found a wide range of uses from classification to storing a lexicon. It operates as follows (see Figure 1). The SOM consists of two layers, an input layer and the map. Each unit in the map has a vector of weights associated with it that is the same size as that of the input layer. When an input is presented to the SOM, the unit whose weight vector is closest to the input vector is selected as a winner.

[1] Also known as instance based learning.

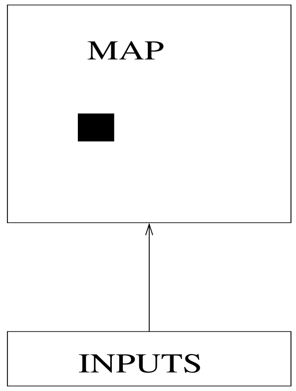

Figure 1: The Self-Organising Map. The map units respond to the inputs. The map unit whose weight vector is closest to the input vector becomes the winner. During training, after a winner is chosen, the weight vectors of the winner and a neighbourhood of surrounding units are nudged towards the current input.

During training, the weight vectors of winning unit and a set of units within the neighbourhood of the winner are nudged, by an amount determined by the learning rate, towards the input vector. Over time the size of the neighbourhood is decreased. Sometimes the learning rate may be too. At the end of training, the units form a map of the input space that reflects how the input space was sampled in the training data. In particular areas of input space in which there were a lot of inputs will be mapped in finer detail, using more units than areas where the inputs were sparsely distributed.

3 Why use a SOM for memory editing

The SOM was chosen because the input is matched to the unit with the closest weight vector. Thus it is motivated by the same principle as used to find the closest match in MBL. It is thus hoped that the SOM can minimise the risk of failing to select the closest match, since the subset will be chosen according to similarity.

However, Daelemans *et al* (1999b) claim that, in language learning, pruning the training items is harmful. When they removed items from the memory base on the basis of their typicality (i.e. the extent to which the items were representative of other items belonging to the same class) or their class prediction strength (i.e. the extent to which the item formed a predictor for its class), the generalisation performance of the MBL system dropped across a range of language learning tasks.

The memory editing approach used by Daelemans *et al* removes training items independently of the novel items, and the remainder are used for matching with all novel items. If one selects a *different* subset for each novel item based on similarity to the novel item, then maybe the risk of degrading performance in memory editing will be reduced. This work aims to achieve precisely this.

4 A hybrid SOM/MBL classifier

4.1 Labelled SOM and MBL (LSOMMBL)

A modified SOM was developed called Labelled SOM. Training proceeds as follows:

- Each training item has an associated label. Initially all the map units are unlabelled.
- When an item is presented, the closest unit out of those with the same label as the input and those that are unlabelled is chosen as the winner. Should an unlabelled unit be chosen it gets labelled with the input's label.
- The weights for neighbouring units are updated as with the standard SOM if they share the same label as the input or are unlabelled.
- When training ends, all the training inputs are presented to the SOM and the winners for each training input noted. Unused units are discarded.

Testing proceeds as follows:

- When an input is presented a winning unit is found *for each category*.
- The closest match is selected from the training items associated with each of the winning units found.
- The most frequent classification for that match is chosen.

It is thus hoped that the closest matches for each category are found and that these will include the closest match amongst them.

Assuming each unit is equally likely to be chosen, the average number of comparisons here is given by $C(N + I/N)$ where C is the number of categories, N is the number of units in the map and I is the number of training items. Choosing $N = \sqrt{I}$ minimises comparisons to $2C\sqrt{I}$. In the experiments the size of the map was chosen to be close to $\sqrt{I}$. This system is referred to as LSOMMBL.

4.2 SOM and MBL (SOMMBL)

In the experiments, a comparison with using the standard SOM in a similar manner was performed. Here the SOM is trained as normal on the training items.

At the end of training each item is presented to the SOM and the winning unit noted as with the modified SOM above. Unused units are discarded as above.

During testing, a novel item is presented to the SOM and the top C winners chosen (i.e. the C closest map units), where C is the number of categories. The items associated with these winners are then compared with the novel item and the closest match found and then the most frequent classification of that match is taken as before. This system is referred to as SOMMBL.

5 The task: Base NP chunking

The task is base NP chunking on section 20 of the Wall Street Journal corpus, using sections 15 to 18 of the corpus as training data as in (Ramshaw and Marcus, 1995). For each word in a sentence, the POS tag is presented to the system which outputs whether the word is inside or outside a base NP, or on the boundary between 2 base NPs.

Training items consist of the part of speech (POS) tag for the current word, varying amounts of left and right context (POS tags only) and the classification frequencies for that combination of tags. The tags were represented by a set of vectors. 2 sets of vectors were used for comparison. One was an orthogonal set with a vector of all zeroes for the "empty" tag, used where the context extends beyond the beginning/end of a sentence. The other was a set of 25 dimensional vectors based on a representation of the words encoding the contexts in which each word appears in the WSJ corpus. The tag representations were obtained by averaging the representations for the words appearing with each tag. Details of the method used to generate the tag representations, known as lexical space, can be found in (Zavrel and Veenstra, 1996). Reilly (1998) found it beneficial when training a simple recurrent network on word prediction.

The self-organising maps were trained as follows:

- For maps with 100 or more units, the training lasted 250 iterations and the neighbourhood started at a radius of 4 units, reducing by 1 unit every 50 iterations to 0 (i.e. where only the winner's weights are modified). The learning rate was constant at 0.1.

- For the maps with 6 units, the training lasted 90 iterations, with an initial neighbourhood of 2, reducing by one every thirty iterations.

- For the maps with 30 units, the training lasted 150 iterations, with an initial neighbourhood of 2, reduced by one every 50 iterations. A single training run is reported for each network since the results did not vary significantly for different runs.

These map sizes were chosen to be close to the square root of the number of items in the training set. No attempt was made to systematically investigate whether these sizes would optimise the performance of the system. They were chosen purely to minimise the number of comparisons performed.

6 Results

Table 1 gives the results of the experiments. The columns are as follows:

- "features". This column indicates how the features are made up.
  "lex" means the features are the lexical space vectors representing the POS tags. "orth" means that orthogonal vectors are used. "tags" indicates that the POS tags themselves are used. MBL uses a weighted overlap similarity metric while SOMMBL and LSOMMBL use the euclidean distance.

	features	window	Chunk fscore	Chunk tag accuracy	Max comparisons (% of items)
LSOMMBL	lex	0-0	79.99	94.48%	87 (197.7%)
LSOMMBL	lex	1-0	86.13	95.77%	312 (30.3%)
LSOMMBL	lex	1-1	**89.51**	96.76%	2046 (20.4%)
LSOMMBL	lex	2-1	88.91	96.42%	2613 (6.8%)
LSOMMBL	orth	0-0	79.99	94.48%	87 (197.7%)
LSOMMBL	orth	1-0	86.09	95.76%	702 (68.1%)
LSOMMBL	orth	1-1	89.39	96.75%	1917 (19.1%)
LSOMMBL	orth	2-1	88.71	96.52%	2964 (7.7%)
SOMMBL	lex	0-0	79.99	94.48%	51 (115.9%)
SOMMBL	lex	1-0	86.11	95.77%	327 (31.7%)
SOMMBL	lex	1-1	**89.47**	96.74%	1005 (10.0%)
SOMMBL	lex	2-1	88.98	96.48%	1965 (5.1%)
SOMMBL	orth	0-0	79.99	94.48%	42 (95.5%)
SOMMBL	orth	1-0	86.08	95.75%	306 (29.7%)
SOMMBL	orth	1-1	89.38	96.77%	1365 (13.6%)
SOMMBL	orth	2-1	88.61	96.45%	2361 (6.1%)
MBL	tags	0-0	79.99	94.48%	44 (100.0%)
MBL	tags	1-0	86.14	95.78%	1031 (100.0%)
MBL	tags	1-1	89.57	96.80%	10042 (100.0%)
MBL	tags	2-1	89.81	96.83%	38465 (100.0%)
MBL	lex	0-0	79.99	94.70%	44 (100.0%)
MBL	lex	1-0	86.14	95.95%	1031 (100.0%)
MBL	lex	1-1	89.57	96.93%	10042 (100.0%)
MBL	lex	2-1	**89.81**	96.96%	38465 (100.0%)
MBL	orth	0-0	79.99	94.70%	44 (100.0%)
MBL	orth	1-0	86.12	95.94%	1031 (100.0%)
MBL	orth	1-1	89.46	96.89%	10042 (100.0%)
MBL	orth	2-1	89.55	96.87%	38465 (100.0%)

Table 1: Results of base NP chunking for section 20 of the WSJ corpus, using SOMMBL, LSOMMBL and MBL, training was performed on sections 15 to 18. The fscores of the best performers in each case for LSOMMBL, SOMMBL and MBL have been highlighted in **bold**.

- "window". This indicates the amount of context, in the form of "left-right" where "left" is the number of words in the left context, and "right" is the number of words in the right context.
- "Chunk fscore" is the fscore for finding base NPs. The fscore (F) is computed as $F = \frac{2PR}{P+R}$ where P is the percentage of base NPs found that are correct and R is the percentage of base NPs defined in the corpus that were found.
- "Chunk tag accuracy" gives the percentage of correct chunk tag classifications. This is provided to give a more direct comparison with the results in (Daelemans et al., 1999a). However, for many NL tasks it is not a good measure and the fscore is more accurate.
- "Max comparisons". This is the maximum number of comparisons per novel item computed as $C(N + X)$ where C is the number of categories, N is the number of units and X is the maximum number of items associated with a unit in the SOM. This number depends on how the map has organised itself in training. The number given in brackets here is the percentage this number represents of

window	SOM size	Training items
0-0	10	44
1-0	30	1131
1-1	100	10042
2-1	200	38465

Table 2: Network sizes and number of training items

the maximum number of comparisons under MBL. The average number of comparisons is likely to be closer to the average mentioned in Section 4.1.

Table 2 gives the sizes of the SOMs used for each context size, and the number of training items.

For small context sizes, LSOMMBL and MBL give the same performance. As the window size increases, LSOMMBL falls behind MBL. The worst drop in performance is just over 1.0% on the fscores (and just over 0.5% on chunk tag accuracy). This is small considering that e.g. for the largest context the number of comparisons used was at most 6.8% of the number of training items.

To investigate whether the method is less risky than the memory editing techniques used in (Daelemans et al., 1999b), a re-analysis of their data in performing the same task, albeit with lexical information, was performed to find out the exact drop in the chunk tag accuracy.

In the best case with the editing techniques used by (Daelemans et al., 1999b), the drop in performance was 0.66% in the chunk tag accuracy with 50% usage (i.e. 50% of the training items were used). Our best involves a drop of 0.23% in chunk tag accuracy and only 20.4% usage. Furthermore their worst case involves a drop of 16.06% in chunk tag accuracy again at the 50% usage level, where ours involves only a 0.54% drop in accuracy at the 6.8% usage level. This confirms that our method may be less risky, although a more direct comparison is required to demonstrate this in a fully systematic manner. For example, our system does not use lexical information in the input where theirs does, which might make a difference to these results.

Comparing the SOMMBL results with the LSOMMBL results for the same context size and tagset, the differences in performance are insignificant, typically under 0.1 points on the fscore and under 0.1% on the chunk tag accuracy. Furthermore the differences sometimes are in favour of LSOMMBL and sometimes not. This suggests they may be due to noise due to different weight initialisations in training rather than a systematic difference.

Thus at the moment it is unclear whether SOMMBL or LSOMMBL have an advantage compared to each other. It does appear however that the use of the orthogonal vectors to represent the tags leads to slightly worse performance than the use of the vectors derived from the lexical space representations of the words.

7 Discussion and future work

The results suggest that the hybrid system presented here is capable of significantly reducing the number of comparisons made without risking a serious deterioration in performance. Certainly, the reduction in the number of comparisons was far greater than with the sampling techniques used by Daelemans *et al* while yielding similar levels of deterioration.

Given that a systematic investigation into what the optimal training regimes and network sizes are has not been performed the results thus seem promising.

With regard to the network sizes, for example, one reviewer commented that choosing the number of units to be the square root of the number of training items may not be optimal since the clusters formed in self-organising maps theoretically vary as the squared cube root of the density, thus implying that a larger number of units may offer better performance. What impact using this insight would have on the performance (as opposed to the speed) of the system however is unclear. Another variable that has not been systematically investigated is the optimal number of winning units to choose during testing. Increasing this value should allow tuning of the system to balance deterioration of the performance against the reduction in comparisons made.

Another issue regards the nature of the comparisons made. When choosing a winning unit, the input is compared to the centroid of the cluster each unit represents. However this fails to take into account the distribution of the items around the centroid. As one reviewer suggested, it may be that if instead the comparison is made with the periphery of the cluster there would be a reduced risk of missing the closest item. One possibility for taking this into account would be to compute the average distance of the items from the centroid and subtract this from the raw distance computed between the input and the centroid. This would take into account how spread out the cluster is as well as how far the centroid is from the input item. This would be a somewhat more expensive comparison to make but may be worthwhile to improve the probability that the closest item is found in the clusters that are searched.

Future work will therefore include systematically investigating these issues to determine the optimal parameter settings. Also a more systematic comparison with other sampling techniques, especially other methods of clustering, is needed to confirm that this method is less risky than other techniques.

8 Conclusion

This work suggests that using the SOM for memory editing in MBL may be a useful technique for improving the speed of MBL systems whilst minimising reductions in performance. Further work is needed however to find the optimal training parameters for the system and to confirm the utility of this approach.

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