The purpose of this research was to study the effect of different reordering schemes on the performance of CPD which is a sparse tensor computation used in training neural networks.

**What is a tensor?**
A tensor is a generalization of a matrix or a vector; in other words, a tensor is an n-dimensional structure containing data.

**What does it mean for a tensor to be sparse?**
This means that the tensor has a lot of 0’s. Due to the relative size of the tensor to the few non-zero elements, we would like to form a data structure that does not do computations on the zero elements and moves the non-zero elements close to each other in memory.

**What is CPD?**
CPD is a complicated tensor computation that “attempts to decompose a tensor into a set of rank-one tensors” known by two names: 1. Canonical Polyadic Decomposition 2. CANDECOMP/PARAFAC Decomposition.

**How could a reordering scheme affect the speed of CPD?**
Reordering schemes can theoretically improve both spatial locality and temporal locality.
- Temporal locality is the reuse of data within a short period of time.
- Spatial Locality is the use of relatively close storage locations.

**Example: A 3-dimensional tensor reordered to show greater spatial locality**

```
0 3 0 3 0 0 0 0 0 0 0 2 0 2 0 0 2
0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 3 0 3 0 0 0 0 0 0 0 2 0 2 0 0 2
```

Figure 1A demonstrates that a 3-way partition ordering is always faster than a 6-way partition ordering. Excluding nips, which was ordered 22x faster via a 3-way partition than a 6-way partition, a 3-way partition averages to be over 3% faster than a 6-way partition ordering. Figure 1B displays the scalability of Lexi-Order, since the time to order the tensors decreases with more cores on each tensor.

We observe that SPLATT, both 3-way and 6-way partitioning, is faster sequentially on nell-2, crime, and enron; Lexi-Order is faster sequentially on nell-1, nips, flickr, and delicious. Thus, the performance in serial is dependent on the tensor. However, when parallelism is introduced, since Lexi-Order scales well and SPLATT does not, Lexi-Order is consistently faster with the higher core counts. Thus, with both 8 and 32 cores, Lexi-Order is much faster than either of SPLATT’s orderings. Overall, we observe that Lexi-Order is more efficient.

**Results**

<table>
<thead>
<tr>
<th>Tensor Suite</th>
<th>Dimensions</th>
<th>Non-Tensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>nell-1</td>
<td>2.920M x 2.143M x 25.905M</td>
<td>143.6M</td>
</tr>
<tr>
<td>nell-2</td>
<td>12.09K x 9.184K x 28.82K</td>
<td>76.85M</td>
</tr>
<tr>
<td>nips</td>
<td>2.482K x 2.862K x 14.04K</td>
<td>3.101M</td>
</tr>
<tr>
<td>crime</td>
<td>8.198K x 24 x 77 x 32</td>
<td>5.300M</td>
</tr>
<tr>
<td>enron</td>
<td>6.068K x 5.699K x 24.34K x 1.17K</td>
<td>54.20M</td>
</tr>
<tr>
<td>flickr</td>
<td>319.7K x 28.15M x 1.607M x 7.91</td>
<td>112.9M</td>
</tr>
<tr>
<td>delicious</td>
<td>532.9K x 17.28M x 2.483M x 1.44K</td>
<td>140.1M</td>
</tr>
</tbody>
</table>

Figure 2 displays a measure of speedup acquired by an ordering on each tensor with different core counts. This number is acquired by dividing the time taken by CPD on a tensor with no reordering by the time taken by CPD on a tensor with an ordering. In other words:

\[
\text{Speedup} = \frac{\text{time with no ordering}}{\text{time with ordering}}
\]

Therefore, points above the line (>1) indicate a speedup caused by the reordering; points below the line indicate a slowdown. Note that not all points lie above the line, since these are just heuristics. However, averaged across all seven tensors, there tends to be a speedup. The results made it difficult to access which ordering is the most effective.

**Impact**
This research is the:
- First work to compare different ordering schemes, besides the paper that introduced Lexi-Order – it will thus be a guideline for future research in the field.
- It was found that Lexi Order is much more efficient, and that Lexi-Order and 3-Partition SPLATT are similarly effective, since they see similar average speedup.

**References**
5. Li, Jiajia et al. – https://github.com/ShahidMrHiParTi.

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