Overview

- Multi-step reasoning problems are hard for machine learning due to the non-smooth loss functions associated with them. General math problems fall in this category.
- Education studies show that humans learn math by doing example problems and comparing intermediate steps.
- **OUR GOAL:** By supplying intermediate steps as additional labels, we aim to **shape the loss function** and improve accuracy.

Methods

**Linear Regression**

As a simple baseline, we used linear regression with a **polynomial based kernel** along with L2 regularization to reduce overfitting.

Dataset was modified to allow for use by linear regression:
- Complex questions requiring linguistic parsing were omitted
- Problems were converted from strings to vectors
- Question lengths were fixed

**Long Short-Term Memory (LSTM)**

LSTM is a type of recurrent neural network (RNN) which has feedback connections and can handle sequential data. We thus used sequence-to-sequence LSTMs with and without attention as more complex baselines.

**Transformer**

The Transformer model's key feature is a self-attention mechanism, allowing it to better retain relationships between distant characters than LSTMs.

Because of this, the Transformer often has more success parsing complex phrases than an LSTM, as indicated by DeepMind’s results.

Results

<table>
<thead>
<tr>
<th>Linear regression:</th>
<th>Addition Only</th>
<th>Multiplication Only</th>
<th>Mixed Arithmetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>No intermediate steps</td>
<td>100%</td>
<td>100%</td>
<td>0.7%</td>
</tr>
<tr>
<td>With intermediate steps</td>
<td>100%</td>
<td>100%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

Linear regression is too simple for these types of problems. **Intermediate steps have no effect**

Dataset

We used a mathematics dataset containing text question and answer pairs on a variety of mathematics topics **released by Google’s Deepmind** in 2019. An example question-answer pair is:

**Q:** Find the second derivative of $q^5 - 391q^4 + 1600q^2$

**A:** $20q^3 - 4692q^2 + 3200$

We modified the dataset by supplying intermediate steps as additional labels for amenable problem types which gave the Transformer model difficulty in Google’s DeepMind paper. An example modified question-answer pair is:

**Q:** Calculate $(-168)/(-2) + (28 - 74)$.

**A:** $168 / 2 + (28 + -74)||84 + (28 + -74)||84 + -46||38||$

where ‘||’ denotes the end of a step

Future Work

Perform grid search for hyperparameters using additional computational resources for LSTM and Transformer models to better understand what types of architectures best benefit from intermediate steps.