Report on Positional Encoding in Transformers

Introduction

Positional encoding is crucial in transformers since, unlike RNNs and LSTMs, transformers process words in parallel, losing the sequential order information. Positional encoding introduces a mechanism to capture the position of words in a sequence, essential for understanding context.

Initial Approach

The initial method added a scalar to each word to store its position. However, this approach had significant drawbacks:

1. **Unbounded Values:** There was no upper limit to the scalar values, making it impractical for long sequences.
2. **Relative Position Ignored:** The method did not capture the relative positions between words effectively.

Sinusoidal Encoding

To address these issues, sinusoidal functions were introduced. Specifically, the sine function sin(pos) was used. This method resolved the drawbacks of the initial approach:

1. **Bounded Values:** The sine function outputs values between -1 and 1.
2. **Relative Position:** Sinusoidal encoding captures relative positions due to its periodic nature.

Study and Findings

A study was conducted using positional vectors with a sequence length of 100 and a dimension of 5. Key findings were:

- As the dimensions increased, the values approached zero.
- Plotting the sine of all columns revealed that the sine waves intersected at the least common multiple (LCM) of their periods(wavelengths), causing the waves to restart periodically.

Introducing Cosine Functions

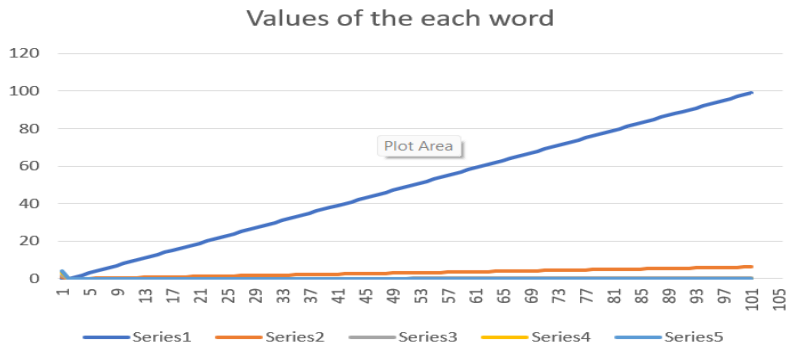
To further refine the encoding and prevent wave intersection:

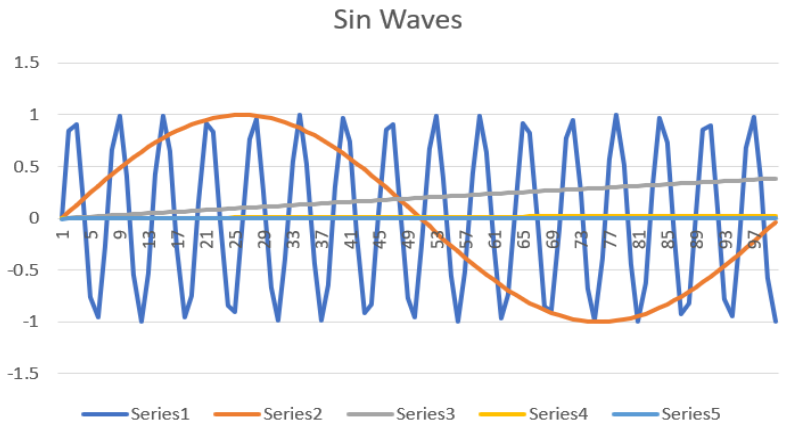
- **Sine for Even Positions:** $PE(pos,2i)=sin(pos/100002i/d)$
- **Cosine for Odd Positions:** $PE(pos,2i+1)=cos(pos/100002i/d)$
- This combined approach ensured that the sine and cosine waves did not intersect, providing a unique positional encoding for each word position.

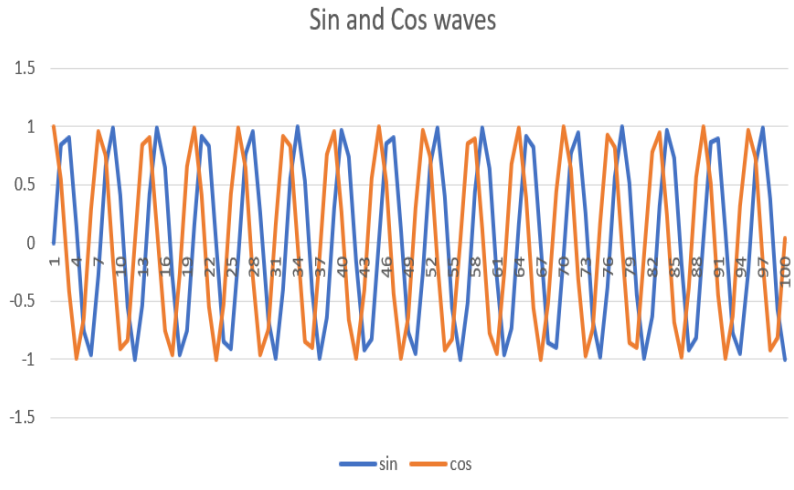
Conclusion

Positional encoding using sinusoidal functions effectively captures word positions in transformer models. The combined use of sine and cosine functions ensures bounded, non-intersecting values, preserving both absolute and relative positions in the sequence.

References:https://colab.research.google.com/drive/17vfKAXEQUM7cWkDJ5TWTqu8zDkBbzrrS#scrollTo=dk7DD-TS9yWs


Values of the each word
120
100
80
60
40
20
0
Plot Area
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105
Series1
Series2
Series3
Series4
Series5


Sin Waves
1.5
1
0.5
0
-0.5
-1
-1.5
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97
Series1
Series2
Series3
Series4
Series5


Sin and Cos waves
1.5
1
0.5
0
-0.5
-1
-1.5
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100
sin
cos