# CS - 6320 Natural Language Processing Fall 2020

## **Course Project**

| Name                | NetID     |
|---------------------|-----------|
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## A. Project Description

Design and implementation of models for extracting semantic relations between two named entities in a sentence. There are two named entities "e1" and "e2" in a sentence. A relation and its direction that holds between the two entities is provided. We had to design an algorithm to learn from the training examples and classify the entities among the following relations: Entity-Destination, Cause-Effect, Instrument-Agency, Content-Container, Component-Whole, Entity-Origin, Message-Topic, Product-Producer, Member-Collection, and Other.

## **B.** Proposed solution

We studied few examples from the training dataset to understand the relation between the entities "e1" and "e2". There are different types of cases that relate the two words.

#### Example 1:

Arcane Subtlety reduced the threat caused by Polymorph by 40% at max rank, though the  $\langle e1 \rangle$  threat  $\langle e1 \rangle$  caused by the  $\langle e2 \rangle$  spell  $\langle e2 \rangle$  is minimal.

Relation: Cause-Effect(e2,e1)

We see that the phrase "caused by" in between the two entities give a hint towards a Cause-Effect relation.

#### Example 2:

Many other  $\langle e1 \rangle$  dwarves  $\langle e1 \rangle$  also hailed from this infamous  $\langle e2 \rangle$  clan  $\langle e2 \rangle$ .

Relation: Entity-Origin(e1,e2).

We see that the phrase "hailed from" in between the two entities give a hint towards a Entity-Origin relation.

#### Example 3:

This book has transported < e1> readers < /e1> into < e2> ancient times < /e2>.

*Relation: Entity-Destination(e1,e2)* 

We see that the phrase "into" in between the two entities give a hint towards a Entity-Destination relation.

#### 1. Lexical Features

We check the lexical features in the sentence first. We find that the words in between play a major role in deciding the relation between the two entities. But the word varies in different cases. Sometimes it is the verb that decides the relation, sometimes it is the preposition; and other times it may be the determiners.

So, we take one word before entity one "e1", a word after entity two "e2" and 6 words in between both the entities for our consideration and analysis of the data.

#### 2. Dependency Features

Next, we check the dependency features on the entities. Here, we check the dependency of the nominals with the root verb and try to find a relation between the entities through the root verb.

#### 3. Synsets

We are also finding the hypernyms, hyponyms, meronyms and holonyms (NLTK-wordnet) of the entities. Finally, we are using Spacy to get the named entities of the entities.

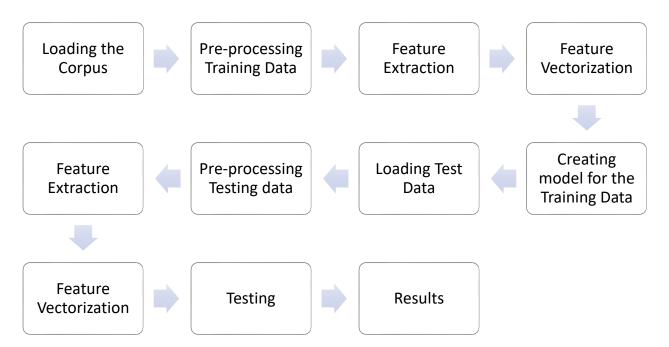
## **C.** Implementation Details

Writing this code required us to understand the basics of English grammar and sentence formation. We have implemented our code in Python Programming Language.

#### Libraries used:

- spacy
- nltk
- time
- sklearn
- verbnet
- wordnet
- csv

## **Algorithm Architecture:**



#### **Calculations:**

For a confusion matrix with actual values vs predicted values, the precision and recall is calculated by:

#### Precision:

Fraction of docs assigned class *i* that are actually about class *i*:

$$\frac{c_{ii}}{\sum_{j} c_{ji}}$$

#### Recall:

Fraction of docs in class *i* classified correctly:

$$\frac{c_{ii}}{\sum_{j} c_{ij}}$$

And F-score is given by: 
$$\frac{2PR}{(P+R)}$$

Example below shows an illustration of the calculations:

#### Predicted

| Actual | cat | dog | pig | Count |
|--------|-----|-----|-----|-------|
| cat    | 2   | 2   |     | 4     |
| dog    | 1   | 1   | 1   | 3     |
| pig    |     | 2   | 1   | 3     |

Macro

|   |           | cat    | dog    | pig    | Averaging |
|---|-----------|--------|--------|--------|-----------|
|   | Precision | 0.6667 | 0.2000 | 0.5000 | 0.455556  |
|   | Recall    | 0.5000 | 0.3333 | 0.3333 | 0.388889  |
|   | F-Score   | 0.5714 | 0.2500 | 0.4000 | 0.407143  |
| ľ | Accuracy  | 40.00% |        |        |           |

## D. Results and Analysis

### a. Details of Training process:

| Other 0.21526157947350882 0.9946112394149346 0.3539241199835639<br>Entity-Destination(e1,e2) 0.961335676625659 0.7169069462647444 0.8213213213213<br>Cause-Effect(e2,e1) 0.8436830835117773 0.6501650165016502 0.7343895619757688                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Total time taken for training<br>Classes | : 4809 seconds.<br>Count |                      |                      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|--------------------------|----------------------|----------------------|
| Cause_Effect(e2,e1) 606 Instrument-Agency(e2,e1) 372 Content-Container(e1,e2) 334 Component-Whole(e1,e2) 518 Message_Topic(e1,e2) 444 Entity-Origin(e1,e2) 138 Product_Producer(e2,e1) 359 Cause_Effect(e1,e2) 439 Message_Topic(e1,e2) 549 Message_Topic(e1,e2) 549 Message_Topic(e1,e2) 549 Message_Topic(e2,e1) 134 Product_Producer(e2,e1) 134 Product_Producer(e2,e1) 134 Product_Producer(e1,e2) 288 Content-Container(e2,e1) 438 Content-Container(e2,e1) 153 Member_Collection(e2,e1) 438 Content-Container(e2,e1) 153 Member_Collection(e1,e2) 91 Entity-Destination(e2,e1) 1 Classes Precision Recall F-Score  Other 0.21526157947350882 0.9946112394149346 0.3539241199835639 Entity-Destination(e2,e1) 1 Classes Precision Recall F-Score  Other 0.8436839835117773 0.5591659165916591659165916591659165916591                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <br>Other                                | 1299                     |                      |                      |
| Instrument-Agency(e2,e1) 372 Component-Whole(e1,e2) 334 Component-Whole(e1,e2) 518 Message-Topic(e1,e2) 444 Entity-Origin(e2,e1) 359 Cause-Effect(e1,e2) 319 Member-Collection(e2,e1) 359 Component-Whole(e1,e2) 438 Component-Whole(e2,e1) 359 Cause-Effect(e1,e2) 319 Member-Collection(e2,e1) 438 Component-Whole(e2,e1) 153 Member-Collection(e1,e2) 70 Instrument-Agency(e1,e2) 91 Entity-Destination(e2,e1) 1  Classes Precision Recall F-Score  Other Origin(e1,e2) 91 Entity-Destination(e2,e1) 1  Classes Precision Recall F-Score  Other Origin(e1,e2) 91 Entity-Destination(e1,e2) 92 Entity-Destination(e2,e1) 1  Classes Precision Recall P-Score  Other Origin(e1,e2) 92 Entity-Destination(e1,e2) 93 Entity-Destination(e1,e2) 94 Entity-Destination(e1,e2) 95 Entity-Destination(e1,e2) 95 Entity-Destination(e1,e2) 96 Entity-Destination(e1,e2) 97 Entit | Entity-Destination(e1,e2)                | 763                      |                      |                      |
| Component-Whole(e1,e2) 424 Component-Whole(e1,e2) 424 Entity-Origin(e1,e2) 518 Wessage-Topic(e1,e2) 444 Entity-Origin(e2,e1) 138 Product-Producer(e2,e1) 359 Cause-Effect(e1,e2) 319 Wember-Collection(e2,e1) 134 Product-Producer(e1,e2) 288 Component-Whole(e2,e1) 153 Wember-Collection(e1,e2) 70 Instrument-Agency(e1,e2) 91 Entity-Destination(e1,e2) 70 Instrument-Agency(e1,e2) 91 Entity-Destination(e1,e2) 10 Cause-Effect(e2,e1) 10 Classes Precision Recall F-Score Product-Producer(e2,e1) 10 Classes Precision Recall F-Score Product-Producer(e2,e2) 91 Entity-Destination(e1,e2) 0.961335676625659 0.716906946247444 0.82132132132132 Cause-Effect(e2,e1) 0.8345630835117773 0.659155016591265914 0.9625251989399294 Content-Container(e1,e2) 0.9329769239769231 0.1437125748502994 0.2652519893899294 Content-Container(e1,e2) 0.9347619047619048 0.04481132075471698 0.0853932584269663 Entity-Origin(e1,e2) 0.9876543209876543 0.154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154440154401544015440154401544015440154401544015440154401544015440154401544 | Cause-Effect(e2,e1)                      | 606                      |                      |                      |
| Component-Whole(e1,e2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Instrument-Agency(e2,e1)                 | 372                      |                      |                      |
| ### State                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                          | 334                      |                      |                      |
| Message-Topic(e1,e2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Component-Whole(e1,e2)                   | 424                      |                      |                      |
| Entity-Origin(e2,e1) 138 Product-Produccer(e2,e1) 359 Cause-Effect(e1,e2) 319 Member-Collection(e2,e1) 549 Message-Topic(e2,e1) 134 Product-Producer(e1,e2) 288 Component-Whole(e2,e1) 438 Content-Container(e2,e1) 153 Member-Collection(e1,e2) 70 Instrument-Agency(e1,e2) 91 Entity-Destination(e2,e1) 1  Classes Precision Recall F-Score  Other 0.21526157947350882 0.9946112394149346 0.3539241199835639 Cintity-Destination(e1,e2) 0.961335676625659 0.71699642647444 0.821321321321321 Clause-Effect(e2,e1) 0.8436830835117773 0.6590165016502 0.734389561957688 Content-Container(e1,e2) 0.99230769231 0.1437125748562994 0.24870466321243523 Component-Whole(e1,e2) 0.9947619047619048 0.0488132074716998 0.085393258426965 Entity-Origin(e1,e2) 0.9876543209876543 0.154440154444 0.26711185308848084 Message-Topic(e1,e2) 1.0 0.0252525225252525 0.04405286343612334 Cnitity-Origin(e2,e1) 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0  Product-Producer(e1,e2) 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0  Product-Producer(e1,e2) 0.0 0.0  Product-Pro | Entity-Origin(e1,e2)                     | 518                      |                      |                      |
| Product-Producer(e2,e1) 359 Cause-Effect(e1,e2) 319 Message-Topic(e2,e1) 134 Product-Producer(e1,e2) 288 Component-Whole(e2,e1) 438 Content-Container(e2,e1) 153 Member-Collection(e1,e2) 70 Entity-Destination(e2,e1) 1  Classes Precision Recall F-Score Entity-Destination(e2,e1) 0.961336676625659 0.716906462647444 0.82132132132132 Cause-Effect(e2,e1) 0.843683083511773 0.6501650165012 0.7343895619757688 Entity-Destination(e1,e2) 0.9230769230769231 0.1437125748502994 0.2652518983899204 Component-Whole(e1,e2) 0.9947619047619048 0.04481132075471698 0.0853932584269663 Entity-Origin(e1,e2) 0.9876543209876543 0.15444015444015444 0.26711185308848084 Message-Topic(e1,e2) 1.0 0.0 0.0 Product-Producer(e2,e1) 0.0 0.0 Product-Producer(e2,e1) 0.0 0.0 Product-Producer(e2,e1) 0.0 0.0 Message-Topic(e2,e1) 0. | Message-Topic(e1,e2)                     | 444                      |                      |                      |
| Tause-Effect(e1,e2) 319                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Entity-Origin(e2,e1)                     | 138                      |                      |                      |
| Member-Collection(e2,e1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                          | 359                      |                      |                      |
| Message-Topic(e2,e1) 134 Product-Producer(e1,e2) 288 Component-Whole(e2,e1) 438 Content-Container(e2,e1) 153 Member-Collection(e1,e2) 70 Instrument-Agency(e1,e2) 91 Entity-Destination(e2,e1) 1  Classes Precision Recall F-Score Cther 0.21526157947350882 0.9946112394149346 0.3539241199835639 Entity-Destination(e1,e2) 0.961335676625659 0.7169069462647444 0.8213213213213213 Cause-Effect(e2,e1) 0.8436830835117773 0.65016501650165016502 0.7343895619757688 Instrument-Agency(e2,e1) 1.0 0.913440860215053764 0.02652519893899204 Content-Container(e1,e2) 0.9230769230769231 0.1437125748502994 0.24870466321243523 Component-Whole(e1,e2) 0.9047619047619048 0.04481132075471698 0.0853932584269663 Entity-Origin(e1,e2) 0.9876543209876543 0.15444015444015444 0.26711185308848084 Message-Topic(e1,e2) 1.0 0.022522522522522 0.04405286343612334 Entity-Origin(e2,e1) 0.0 0.0 Cause-Effect(e1,e2) 1.0 0.07210031347962383 0.13450292397660818 Member-Collection(e2,e1) 0.967741935483871 0.1092896174863388 0.19639934533551553 Message-Topic(e2,e1) 0.0 0.0 0.0 Product-Producer(e1,e2) 0.0 0.0 0.0 Component-Whole(e2,e1) 1.0 0.0182648401826484 0.03587443946188341 Content-Container(e2,e1) 0.0 0.0 0.0 Content-Container(e2,e1) 0.0 0.0 0.0 Component-Whole(e2,e1) 0.0 0.0 0.0 0.0 Content-Container(e2,e1) 0.0 0.0 0.0 0.0 Content-Container(e2,e1) 0.0 0.0 0.0 0.0 Content-Container(e2,e1) 0.0 0.0 0.0 0.0 0.0 Content-Container(e2,e1) 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.                                                                                                                                                                                                                                                                                                      | Cause-Effect(e1,e2)                      | 319                      |                      |                      |
| Product-Producer(e1,e2) 288 Component-Whole(e2,e1) 438 Content-Container(e2,e1) 153 Member-Collection(e1,e2) 70 Instrument-Agency(e1,e2) 91 Entity-Destination(e2,e1) 1  Classes Precision Recall F-Score  Other 0.21526157947350882 0.9946112394149346 0.3539241199835639 Entity-Destination(e1,e2) 0.961335676625659 0.7169069462647444 0.8213213213213213 Cause-Effect(e2,e1) 0.8436830835117773 0.6501650165016502 0.7343895619757688 Instrument-Agency(e2,e1) 1.0 0.013440860215053764 0.02652519893899204 Content-Container(e1,e2) 0.9230769230769231 0.1437125748502994 0.24870466321243523 Component-Whole(e1,e2) 0.9947619047619048 0.04481132075471698 0.0853932584269663 Entity-Origin(e1,e2) 0.9876543209876543 0.15444015444015444 0.26711185308848084 Message-Topic(e1,e2) 1.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Cause-Effect(e1,e2) 1.0 0.0 0.0 0.0  Cause-Effect(e1,e2) 1.0 0.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Product-Producer(e1,e2) 0.0 0.0 0.0  Product-Producer(e1,e2) 0.0 0.0 0.0  Component-Whole(e2,e1) 0.0 0.0 0.0  Component-Whole(e2,e1) 1.0 0.0 0.082648401826484 0.03587443946188341 0.0960000000000000000000000000000000000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | <pre>//ember-Collection(e2,e1)</pre>     | 549                      |                      |                      |
| Component-Whole(e2,e1) 438 Content-Container(e2,e1) 153 Member-Collection(e1,e2) 70 Instrument-Agency(e1,e2) 91 Entity-Destination(e2,e1) 1  Classes Precision Recall F-Score  Cher 0.21526157947350882 0.9946112394149346 0.3539241199835639 Entity-Destination(e1,e2) 0.961335676625659 0.7169069462647444 0.8213213213213213 Cause-Effect(e2,e1) 0.8436830835117773 0.6501650165016502 0.7343895619757688 Instrument-Agency(e2,e1) 1.0 0.013440860215053764 0.02652519893899204 Content-Container(e1,e2) 0.9230769230769231 0.1437125748502994 0.24870466321243523 Component-Whole(e1,e2) 0.9876543209876543 0.15444015444015444015444 0.26711185308848084 Message-Topic(e1,e2) 1.0 0.0252525252525252 0.04405286343612334 Entity-Origin(e2,e1) 0.0 0.0 0.0 Cause-Effect(e1,e2) 1.0 0.0 0.0 0.0 Component-Whole(e2,e1) 1.0 0.0 0.0 0.0 0.0 0.0 Component-Whole(e2,e1) 1.0 0.0 0.0 0.0 0.0 0.0 0.0 Component-Whole(e2,e1) 1.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0                                                                                                                                                                                                                                                                    |                                          | 134                      |                      |                      |
| Content-Container(e2,e1) 153  Member-Collection(e1,e2) 70  Instrument-Agency(e1,e2) 91  Classes Precision Recall F-Score  Other 0.21526157947350882 0.9946112394149346 0.3539241199835639  Entity-Destination(e1,e2) 0.961335676625659 0.7169069462647444 0.8213213213213213  Cause-Effect(e2,e1) 0.8436830835117773 0.6501650165016502 0.7343895619757688  Instrument-Agency(e2,e1) 1.0 0.013440860215053764 0.02652519893899204  Content-Container(e1,e2) 0.9230769230769231 0.1437125748502994 0.24870466321243523  Component-Whole(e1,e2) 0.9047619047619048 0.04481132075471698 0.0853932584269663  Entity-Origin(e1,e2) 0.9876543209876543 0.154440154440 0.26711185308848084  Message-Topic(e1,e2) 1.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Cause-Effect(e1,e2) 1.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Product-Producer(e1,e2) 0.0 0.0 0.0  Component-Whole(e2,e1) 0.0 0.0 0.0  Product-Producer(e1,e2) 0.0 0.0 0.0  Component-Whole(e2,e1) 0.0 0.0 0.0  Component | ` ,                                      | 288                      |                      |                      |
| ### Precision Recall F-Score    Precision Recall F-Score   Precision Recall Rec |                                          | 438                      |                      |                      |
| Instrument-Agency(e1,e2) 91 Initity-Destination(e2,e1) 1  Classes Precision Recall F-Score  Other 0.21526157947350882 0.9946112394149346 0.3539241199835639 Initity-Destination(e1,e2) 0.961335676625659 0.7169969462647444 0.8213213213213213 Instrument-Agency(e2,e1) 0.8436830835117773 0.6501650165016502 0.7343895619757688 Instrument-Agency(e2,e1) 1.0 0.013440860215053764 0.02652519893899204 Intity-Origin(e1,e2) 0.99230769230769231 0.1437125748502994 0.24870466321243523 Component-Whole(e1,e2) 0.9947619047619048 0.04481132075471698 0.0853932584269663 Intity-Origin(e1,e2) 0.9876543209876543 0.154440154444 0.26711185308848084 Message-Topic(e1,e2) 1.0 0.0225225252525252 0.04405286343612334 Intity-Origin(e2,e1) 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Product-Producer(e1,e2) 0.967741935483871 0.1092896174863388 0.13450292397660818 Message-Topic(e2,e1) 0.0 0.0 0.0  Product-Producer(e1,e2) 0. | ` , ,                                    | 153                      |                      |                      |
| Precision   Recall   F-Score                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | , , ,                                    |                          |                      |                      |
| Precision Recall F-Score  Other 0.21526157947350882 0.9946112394149346 0.3539241199835639 Entity-Destination(e1,e2) 0.961335676625659 0.7169069462647444 0.8213213213213213 Cause-Effect(e2,e1) 0.8436830835117773 0.6501650165016502 0.7343895619757688 Enstrument-Agency(e2,e1) 1.0 0.013440860215053764 0.02652519893899204 Content-Container(e1,e2) 0.9230769230769231 0.1437125748502994 0.24870466321243523 Component-Whole(e1,e2) 0.9047619047619048 0.04481132075471698 0.0853932584269663 Entity-Origin(e1,e2) 0.9876543209876543 0.154440154440 0.26711185308848084 Message-Topic(e1,e2) 1.0 0.02252252522522 0.04405286343612334 Entity-Origin(e2,e1) 0.0 0.0 Product-Producer(e2,e1) 0.0 0.0 Member-Collection(e2,e1) 0.967741935483871 0.1092896174863388 0.19639934533551553 Message-Topic(e2,e1) 0.0 0.0 Product-Producer(e1,e2) 0.0 0.0 Component-Whole(e2,e1) 1.0 0.0182648401826484 0.03587443946188341 Content-Container(e2,e1) 0.0 0.0 Member-Collection(e1,e2) 0.0 0.0 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                          |                          |                      |                      |
| Other 0.21526157947350882 0.9946112394149346 0.3539241199835639   Entity-Destination(e1,e2) 0.961335676625659 0.7169069462647444 0.8213213213213213   Cause-Effect(e2,e1) 0.8436830835117773 0.6501650165016502 0.7343895619757688   Instrument-Agency(e2,e1) 1.0 0.013440860215053764 0.02652519893899204   Content-Container(e1,e2) 0.9230769231 0.1437125748502994 0.24870466321243523   Component-Whole(e1,e2) 0.9047619047619048 0.04481132075471698 0.0853932584269663   Entity-Origin(e1,e2) 0.9876543209876543 0.154440154444 0.26711185308848084   Message-Topic(e1,e2) 1.0 0.02252252252252 0.04405286343612334   Entity-Origin(e2,e1) 0.0 0.0   Cause-Effect(e1,e2) 1.0 0.0 0.0   Cause-Effect(e1,e2) 1.0 0.0 0.0   Cause-Effect(e1,e2) 1.0 0.0 0.0 0.0   Component-Whole(e2,e1) 0.0 0.0 0.0   Member-Collection(e1,e2) 0.0 0.0 0.0 0.0   Member-Collection(e1,e2) 0.0 0.0 0.0 0.0   Member-Collection(e1,e2) 0.0 0.0 0.0 0.0   Instrument-Agency(e1,e2) 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Entity-Destination(e2,e1)                | 1                        |                      |                      |
| Entity-Destination(e1,e2)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Classes                                  | Precision                | Recall               | F-Score              |
| Cause-Effect(e2,e1) 0.8436830835117773 0.6501650165016502 0.7343895619757688 Instrument-Agency(e2,e1) 1.0 0.013440860215053764 0.02652519893899204 Content-Container(e1,e2) 0.9230769230769231 0.1437125748502994 0.24870466321243523 Component-Whole(e1,e2) 0.9047619047619048 0.04481132075471698 0.0853932584269663 Entity-Origin(e1,e2) 0.9876543209876543 0.15444015444 0.26711185308848084 Message-Topic(e1,e2) 1.0 0.0225225252252252 0.04405286343612334 Entity-Origin(e2,e1) 0.0 0.0 Cause-Effect(e1,e2) 1.0 0.0 0.0 Cause-Effect(e1,e2) 1.0 0.0 0.0 0.0 Cause-Effect(e1,e2) 1.0 0.0 0.07210031347962383 0.13450292397660818 Member-Collection(e2,e1) 0.0 0.0 0.0 Product-Producer(e1,e2) 0.0 0.0 0.0 Component-Whole(e2,e1) 1.0 0.0 0.0 Component-Whole(e2,e1) 1.0 0.0 0.08587443946188341 Content-Container(e2,e1) 0.0 0.0 0.0 Member-Collection(e1,e2) 0.0 0.0 0.0 Instrument-Agency(e1,e2) 0.0 0.0 0.0 Instrument-Agency(e1,e2) 0.0 0.0 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Other                                    | 0.21526157947350882      | 0.9946112394149346   | 0.3539241199835639   |
| Instrument-Agency(e2,e1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Entity-Destination(e1,e2)                | 0.961335676625659        | 0.7169069462647444   | 0.8213213213213213   |
| Instrument-Agency(e2,e1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Cause-Effect(e2,e1)                      | 0.8436830835117773       | 0.6501650165016502   | 0.7343895619757688   |
| Component-Whole(e1,e2) 0.9047619047619048 0.04481132075471698 0.0853932584269663 Entity-Origin(e1,e2) 0.9876543209876543 0.15444015444 0.26711185308848084  Message-Topic(e1,e2) 1.0 0.02252252252252 0.04405286343612334  Entity-Origin(e2,e1) 0.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Cause-Effect(e1,e2) 1.0 0.07210031347962383 0.13450292397660818  Member-Collection(e2,e1) 0.0 0.0 0.0  Component-Whole(e2,e1) 0.0 0.0 0.0  Component-Whole(e2,e1) 0.0 0.0 0.0  Component-Whole(e2,e1) 1.0 0.0 0.0  Component-Whole(e2,e1) 1.0 0.0182648401826484 0.03587443946188341  Content-Container(e2,e1) 0.0 0.0  Member-Collection(e1,e2) 0.0 0.0 0.0  Instrument-Agency(e1,e2) 0.0 0.0 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                          | 1.0                      | 0.013440860215053764 | 0.026525198938992044 |
| Entity-Origin(el,e2) 0.9876543209876543 0.15444015444 0.26711185308848084  Message-Topic(e1,e2) 1.0 0.02252252252252 0.04405286343612334  Entity-Origin(e2,e1) 0.0 0.0 0.0  Product-Producer(e2,e1) 0.0 0.0 0.0  Cause-Effect(e1,e2) 1.0 0.07210031347962383 0.13450292397660818  Member-Collection(e2,e1) 0.0 0.0 0.0  Product-Producer(e1,e1) 0.0 0.0 0.0  Product-Producer(e1,e2) 0.0 0.0 0.0  Component-Whole(e2,e1) 0.0 0.0  Component-Whole(e2,e1) 0.0 0.0 0.0  Component-Container(e2,e1) 0.0 0.0 0.0  Member-Collection(e1,e2) 0.0 0.0 0.0  Member-Collection(e1,e2) 0.0 0.0 0.0  Member-Collection(e1,e2) 0.0 0.0 0.0  Instrument-Agency(e1,e2) 0.0 0.0 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Content-Container(e1,e2)                 | 0.9230769230769231       | 0.1437125748502994   | 0.24870466321243523  |
| Message-Topic(e1,e2)       1.0       0.02252252252252252       0.04405286343612334         Entity-Origin(e2,e1)       0.0       0.0       0.0         Product-Producer(e2,e1)       0.0       0.0       0.0         Cause-Effect(e1,e2)       1.0       0.07210031347962383       0.13450292397660818         Member-Collection(e2,e1)       0.967741935483871       0.1092896174863388       0.19639934533551553         Message-Topic(e2,e1)       0.0       0.0       0.0         Component-Whole(e2,e1)       1.0       0.0182648401826484       0.03587443946188341         Content-Container(e2,e1)       0.0       0.0       0.0         Member-Collection(e1,e2)       0.0       0.0       0.0         Instrument-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Component-Whole(e1,e2)                   | 0.9047619047619048       | 0.04481132075471698  | 0.0853932584269663   |
| Entity-Origin(e2,e1) 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Entity-Origin(e1,e2)                     | 0.9876543209876543       | 0.15444015444015444  | 0.26711185308848084  |
| Product-Producer(e2,e1)       0.0       0.0       0.0         Cause-Effect(e1,e2)       1.0       0.07210031347962383       0.13450292397660818         Member-Collection(e2,e1)       0.967741935483871       0.1092896174863388       0.19639934533551553         Message-Topic(e2,e1)       0.0       0.0       0.0         Product-Producer(e1,e2)       0.0       0.0       0.0         Component-Whole(e2,e1)       1.0       0.0182648401826484       0.03587443946188341         Content-Container(e2,e1)       0.0       0.0       0.0         Member-Collection(e1,e2)       0.0       0.0       0.0         Instrument-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Message-Topic(e1,e2)                     | 1.0                      | 0.02252252252252     | 0.04405286343612334  |
| Cause-Effect(e1,e2)       1.0       0.07210031347962383       0.13450292397660818         Member-Collection(e2,e1)       0.967741935483871       0.1092896174863388       0.19639934533551553         Message-Topic(e2,e1)       0.0       0.0       0.0         Product-Producer(e1,e2)       0.0       0.0       0.0         Component-Whole(e2,e1)       1.0       0.0182648401826484       0.03587443946188341         Content-Container(e2,e1)       0.0       0.0       0.0         Member-Collection(e1,e2)       0.0       0.0       0.0         Instrument-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Entity-Origin(e2,e1)                     | 0.0                      | 0.0                  | 0.0                  |
| Member-Collection(e2,e1)       0.967741935483871       0.1092896174863388       0.19639934533551553         Message-Topic(e2,e1)       0.0       0.0       0.0         Product-Producer(e1,e2)       0.0       0.0       0.0         Component-Whole(e2,e1)       1.0       0.0182648401826484       0.03587443946188341         Content-Container(e2,e1)       0.0       0.0       0.0         Member-Collection(e1,e2)       0.0       0.0       0.0         Instrument-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Product-Producer(e2,e1)                  | 0.0                      | 0.0                  | 0.0                  |
| Message-Topic(e2,e1)       0.0       0.0       0.0         Product-Producer(e1,e2)       0.0       0.0       0.0         Component-Whole(e2,e1)       1.0       0.0182648401826484       0.03587443946188341         Content-Container(e2,e1)       0.0       0.0       0.0         Member-Collection(e1,e2)       0.0       0.0       0.0         Instrument-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Cause-Effect(e1,e2)                      | 1.0                      | 0.07210031347962383  | 0.13450292397660818  |
| Product-Producer(e1,e2)       0.0       0.0       0.0         Component-Whole(e2,e1)       1.0       0.0182648401826484       0.03587443946188341         Content-Container(e2,e1)       0.0       0.0       0.0         Member-Collection(e1,e2)       0.0       0.0       0.0         Instrument-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Member-Collection(e2,e1)                 | 0.967741935483871        | 0.1092896174863388   | 0.19639934533551553  |
| Component-Whole(e2,e1)       1.0       0.0182648401826484       0.03587443946188341         Content-Container(e2,e1)       0.0       0.0       0.0         Member-Collection(e1,e2)       0.0       0.0       0.0         Construment-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Message-Topic(e2,e1)                     | 0.0                      | 0.0                  | 0.0                  |
| Content-Container(e2,e1)       0.0       0.0       0.0         Member-Collection(e1,e2)       0.0       0.0       0.0         Instrument-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Product-Producer(e1,e2)                  | 0.0                      | 0.0                  | 0.0                  |
| Member-Collection(e1,e2)       0.0       0.0       0.0         Instrument-Agency(e1,e2)       0.0       0.0       0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Component-Whole(e2,e1)                   | 1.0                      | 0.0182648401826484   | 0.03587443946188341  |
| Instrument-Agency(e1,e2) 0.0 0.0 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Content-Container(e2,e1)                 | 0.0                      | 0.0                  | 0.0                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Member-Collection(e1,e2)                 | 0.0                      | 0.0                  | 0.0                  |
| Entity-Destination(e2,e1) 0.0 0.0 0.0                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Instrument-Agency(e1,e2)                 | 0.0                      | 0.0                  | 0.0                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                          | 0 0                      | 0.0                  | 0.0                  |

We found that our algorithm took around 80 minutes to complete the process. Our training accuracy is 34.054 %. We calculated the precision which was 51.59% and recall which was 15.47%. Our F-score was observed as 0.155168. For the calculation of precision, recall and F-score we used macro averaging method.

## b. Details of Testing process:

| <                                                 | Test Data Details : |                      | >                   |
|---------------------------------------------------|---------------------|----------------------|---------------------|
| Total time taken for testing Classes              | Count               |                      |                     |
| Other                                             | 142                 |                      |                     |
| <pre>Entity-Destination(e1,e2)</pre>              | 81                  |                      |                     |
| Cause-Effect(e2,e1)                               | 65                  |                      |                     |
| <pre>Instrument-Agency(e2,e1)</pre>               | 43                  |                      |                     |
| Content-Container(e1,e2)                          | 41                  |                      |                     |
| Component-Whole(e1,e2)                            | 50                  |                      |                     |
| Entity-Origin(e1,e2)                              | 58                  |                      |                     |
| Message-Topic(e1,e2)                              | 46                  |                      |                     |
| Entity-Origin(e2,e1)                              | 11                  |                      |                     |
| Product-Producer(e2,e1)                           | 41                  |                      |                     |
| Cause-Effect(e1,e2)                               | 30                  |                      |                     |
| Member-Collection(e2,e1)                          | 64                  |                      |                     |
| Message-Topic(e2,e1)                              | 11                  |                      |                     |
| Product-Producer(e1,e2)                           | 38                  |                      |                     |
| Component-Whole(e2,e1)                            | 42                  |                      |                     |
| Content-Container(e2,e1)                          | 18                  |                      |                     |
| Member-Collection(e1,e2)                          | 8                   |                      |                     |
| <pre>Instrument-Agency(e1,e2)</pre>               | 11                  |                      |                     |
| Entity-Destination(e2,e1)                         | 0                   |                      |                     |
| Classes                                           | Precision           | Recall               | F-Score             |
| Other                                             | 0.2002840909090909  | 0.9929577464788732   | 0.3333333333333333  |
| Entity-Destination(e1,e2)                         | 0.8775510204081632  | 0.5308641975308642   | 0.6615384615384615  |
| Cause-Effect(e2,e1)                               | 0.8947368421052632  | 0.5230769230769231   | 0.6601941747572816  |
| Instrument-Agency(e2,e1)                          | 0.0                 | 0.0                  | 0.0                 |
| Content-Container(e1,e2)                          | 1.0                 | 0.0975609756097561   | 0.17777777777777    |
| Component-Whole(e1,e2)                            | 0.0                 | 0.0                  | 0.0                 |
| Entity-Origin(e1,e2)                              | 1.0                 | 0.034482758620689655 | 0.066666666666666   |
| Message-Topic(e1,e2)                              | 0.0                 | 0.0                  | 0.0                 |
| Entity-Origin(e2,e1)                              | 0.0                 | 0.0                  | 0.0                 |
| Product-Producer(e2,e1)                           | 0.0                 | 0.0                  | 0.0                 |
| Cause-Effect(e1,e2)                               | 0.0                 | 0.0                  | 0.0                 |
| Member-Collection(e2,e1)                          | 1.0                 | 0.046875             | 0.08955223880597014 |
| Message-Topic(e2,e1)                              | 0.0                 | 0.0                  | 0.0                 |
| Product-Producer(e1,e2)                           | 0.0                 | 0.0                  | 0.0                 |
| , , ,                                             |                     |                      | 0.0                 |
| Component-Whole(e2,e1)                            | 0.0                 | 0.0                  | 0.0                 |
| Content-Container(e2,e1)                          | 0.0<br>0.0          | 0.0<br>0.0           | 0.0                 |
|                                                   |                     |                      |                     |
| Content-Container(e2,e1)                          | 0.0                 | 0.0                  | 0.0                 |
| Content-Container(e2,e1) Member-Collection(e1,e2) | 0.0<br>0.0          | 0.0<br>0.0           | 0.0<br>0.0          |

Our testing accuracy is 28.375%. We calculated the precision which was 27.62% and recall which was 12.36%. Our F-score was observed as 0.11050. For the calculation of precision, recall and F-score we used macro averaging method.

## E. Summary

We calculated the counts of each classes and checked the accuracy of our training and testing data individually.

Our accuracy is as below:

Training Accuracy: 34.054Testing Accuracy: 28.375

Precision, Recall and F-Score of training and testing data

|          | Precision | Recall   | F-score  |
|----------|-----------|----------|----------|
| Training | 0.515974  | 0.154751 | 0.155168 |
| Testing  | 0.276254  | 0.123657 | 0.110503 |

#### **Problems Encountered:**

One of the main problems that we came across was the huge time it took to train on our dataset. Apart from this there were few issues with the training and testing dataset provided which lead to too much pre-processing time. So, we created a new dataset from the original dataset and cleaned the dataset to avoid some repetitive unnecessary processing to save time and use the new dataset to train our model.

## Pending Issues:

The wordnet sometime did not return anything for hypernyms, holonyms, meronyms and hyponyms. Similarly, Spacy returned no value for NER for some sentences. For unfound or null such cases we are giving the value as "NA" which might cause unnecessary noise in the model. This issue needs to be solved

## Potential Improvements:

We did not find the accuracy of the model to be satisfactory. We felt we could improve the model more by finder better ways to relate the entities and adding more features in the feature vector.

#### F. References

- 1. Bryan Rink and Sanda Harabagiu, Classifying Semantic Relations by Combining Lexical and Semantic Resources, Human Language Technology Research Institute University of Texas at Dallas Richardson, Texas
- 2. Dan Jurafsky || Stanford University, Text classification evaluation, https://www.youtube.com/watch?v=Wq0taCUCSlA&list=PLLssT5z\_DsK8 HbD2sPcUIDfQ7zmBarMYv&index=30&ab\_channel=ArtificialIntelligence -AllinOne
- 3. Scikit-learn module on Precision, Recall and F-score calculation; https://scikit-learn.org/stable/modules/generated/sklearn.metrics.precision\_recall\_fscore\_s upport.html