Lecture: Named Entity Recognition (NER)

Goal:

To understand the concept, applications, and methodologies of Named Entity Recognition (NER), including practical approaches and examples.

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1. Introduction to NER

Definition:
Named Entity Recognition (NER) is a Natural Language Processing (NLP) task that identifies and categorizes named entities in text into predefined categories such as:

- **Person**: Names of individuals (e.g., "Albert Einstein").
- **Organization**: Names of companies or institutions (e.g., "OpenAI").
- **Location**: Places like cities, countries (e.g., "Paris").
- **Date/Time**: Specific dates and times (e.g., "January 1, 2024").
- **Miscellaneous**: Other entities like product names, events, etc.

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2. Applications of NER

- **Information Extraction:** Summarize key facts from large text corpora.
- **Question Answering Systems:** Extract entities to provide accurate answers.
- **Search Engine Optimization:** Enhance search results with specific entities.
- **Chatbots:** Personalize user interactions.
- **Sentiment Analysis:** Understand sentiment about specific entities.

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3. NER Pipeline

1. **Preprocessing:**
    - Tokenization: Break text into words or phrases.
    - Lowercasing, punctuation removal, etc.
2. **Feature Extraction:**
    - Lexical features (e.g., word case, suffixes).
    - Syntactic features (e.g., part-of-speech tags).
    - Semantic features (e.g., word embeddings).
3. **NER Algorithm:**
    - Rule-based methods.
    - Statistical models like Hidden Markov Models (HMMs) or Conditional Random Fields (CRFs).

    - Deep learning models like BiLSTM-CRF or Transformers (e.g., BERT).
4. **Postprocessing:**
    - Resolve ambiguities.
    - Merge overlapping entities.

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4. Methods for NER

A. Rule-based NER:

Uses predefined patterns like regular expressions.
Example:

- Rule: Capitalized words followed by "Inc." → Organization.
- Text: "Apple Inc. launched a new product." → Extract "Apple Inc."

B. Machine Learning-based NER:

- Requires labeled training data.
- Uses algorithms like HMMs, CRFs, or SVMs.

C. Deep Learning-based NER:

- **BiLSTM-CRF:** Combines bidirectional LSTMs with CRFs for sequence tagging.
- **Transformers:** Models like BERT use context-aware embeddings for accurate predictions.

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5. Example: NER with Python

```
import spacy

# Load pre-trained NER model
nlp = spacy.load("en_core_web_sm")

# Input text
text = "Barack Obama was born in Hawaii and served as the President of the
United States."

# Process text
doc = nlp(text)

# Extract entities
for ent in doc.ents:
    print(f"Entity: {ent.text}, Label: {ent.label_}")
```

Output:

```
mathematica
Copy code
Entity: Barack Obama, Label: PERSON
Entity: Hawaii, Label: GPE
Entity: President, Label: TITLE
Entity: United States, Label: GPE
```

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6. Evaluation Metrics for NER

- **Precision:** Fraction of correctly identified entities out of all identified entities.
- **Recall:** Fraction of correctly identified entities out of all actual entities.
- **F1-score:** Harmonic mean of precision and recall.

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7. Challenges in NER

- **Ambiguity:** Words with multiple meanings (e.g., "Apple" as a fruit or company).
- **Context Dependence:** Understanding entities in context (e.g., "Washington" as a place or person).
- **Domain-specific Adaptation:** Adapting to different fields like medicine or law.

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8. Advanced NER Approaches

- **Zero-shot NER:** Identify entities without prior labeled data for a new category.
- **Domain-specific NER:** Models trained for specific domains like healthcare or legal texts.
- **Multilingual NER:** Handle NER tasks across languages.

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9. Assignment/Homework

1. **Practice Task:**
   Use Spacy or another NER library to extract entities from a news article.
   - **Deliverable:** Submit the code and results.
2. **Research Task:**
   Write a short report on the challenges of NER in multilingual settings.

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10. Summary

- NER is a critical task in NLP, enabling systems to extract and categorize key entities in text.
- Advanced models like BiLSTM-CRF and Transformers offer high accuracy.
- NER has wide applications in information extraction, search engines, and chatbots.