```
!pip install transformers datasets seqeval scikit-learn
```

Show hidden output

```
!pip install datasets transformers seqeval scikit-learn pandas
!pip install torch
```

Show hidden output

```
import transformers
import datasets
import torch
```

```
import os
os.makedirs("data", exist_ok=True)

from datasets import load_dataset
import pandas as pd
```

```
# auto_annotate_ner.py
import os
import re
from datasets import load_dataset

# -------- CONFIG --------
OUTPUT_CONLL = "data/auto_ner.conll"
NUM_SAMPLES = None          # increase if you want more
TEXT_COL = "Long Description"   # from your dataset columns

os.makedirs("data", exist_ok=True)

# --- keyword lists (very expandable) ---

PROGRAMMING_LANGS = {
    "python", "java", "javascript", "typescript", "ts", "c", "c++",
    "golang", "rust", "php", "ruby", "scala", "kotlin", "swift", "s
}

FRAMEWORKS = {
    "react", "angular", "vue", "django", "flask", "spring", "spring
```

```
    "spring-boot", "pytorch", "tensorflow", "keras", "node", "nodej
    "node.js", "express", "laravel", "symfony", "rails", "fastapi",
    "asp.net", "asp", ".net", ".netcore", ".net-core", "webapi", "w
    "entity framework", "sqlalchemy", "celery"
}

TOOLS = {
    "aws", "azure", "gcp", "google cloud", "docker", "kubernetes",
    "git", "github", "gitlab", "bitbucket", "jenkins", "jira", "her
    "linux", "snowflake", "bigquery", "redshift", "airflow", "terra
    "ansible", "mongodb", "mongo", "postgres", "postgresql", "mysql
    "oracle", "cassandra", "kafka", "hadoop", "shopify", "ebay", "w
    "excel", "google sheets", "google sheet"
}

SKILL_TECH = {
    "devops", "machine learning", "deep learning", "ml", "dl",
    "microservices", "rest", "graphql", "cloud", "blockchain",
    "e-commerce", "ecommerce", "seo", "ppc", "ci/cd", "ci cd",
    "data engineering", "data analysis", "data analytics",
    "data scientist", "data science"
}

EDU_LEVEL_PATTERNS = [
    r"bachelor'?s degree", r"bachelors degree", r"bachelor degree",
    r"master'?s degree", r"masters degree", r"master degree",
    r"phd", r"ph\.d", r"b\.sc", r"m\.sc", r"bsc", r"msc",
    r"b\.tech", r"m\.tech", r"btech", r"mtech"
]

DEGREE_MAJOR_PATTERNS = [
    "computer science", "software engineering", "information techno
    "data science", "statistics", "mathematics", "electrical engine
    "cs", "it"
]

EMPLOYMENT_TYPE_PATTERNS = [
    "full-time", "full time", "part-time", "part time",
    "contract", "internship", "intern", "freelance", "permanent",
    "temporary"
]

# --- extra helper sets for better JOB_TITLE / COMPANY detection --

JOB_HEAD_NOUNS = {
    "engineer", "developer", "scientist", "manager", "architect",
    "analyst", "specialist", "consultant", "administrator", "devops
    "designer", "director", "lead", "intern", "tester", "qa", "auth
```

```
}

JOB_MODIFIERS = {
    "senior", "sr", "junior", "jr", "principal", "staff", "head",
    "lead", "chief", "associate", "assistant", "graduate"
}

JOB_CONTEXT_WORDS = {
    "software", "data", "backend", "front-end", "frontend", "fullst
    "full-stack", "ml", "ai", "product", "project", "cloud", "secur
    "qa", "test", "testing", "research", "systems", "mobile", "ios"
}

COMPANY_STOPWORDS = {
    "we", "our", "the", "a", "an", "you", "they", "he", "she", "it"
    "for", "with", "to", "of", "in"
}


def normalize(text: str) -> str:
    return text.strip().lower()


def find_span_matches(tokens, phrases, label):
    """
    tokens: list of lowercased tokens
    phrases: set/list of phrases in lowercase (may be multi-word)
    label: label string
    returns list of (start, end, label) spans (end exclusive)
    """
    spans = []
    n = len(tokens)
    phrase_tokens_list = [p.split() for p in phrases]

    for phrase_tokens in phrase_tokens_list:
        m = len(phrase_tokens)
        if m == 0:
            continue
        for i in range(n - m + 1):
            if tokens[i:i+m] == phrase_tokens:
                spans.append((i, i + m, label))
    return spans


def find_regex_spans(text, tokens, label, patterns):
    """
    text: original string
    tokens: list of tokens (original, not lowercased)
```

```
        patterns: list of regex or plain patterns
        returns spans (start_idx, end_idx, label) based on char search
        NOTE: very approximate but okay for auto-label.
        """
        spans = []
        lowered = text.lower()
        # build token char offsets
        offsets = []
        idx = 0
        for tok in tokens:
            start = text.find(tok, idx)
            if start == -1:
                start = idx  # fallback
            end = start + len(tok)
            offsets.append((start, end))
            idx = end

        for pat in patterns:
            # treat as regex
            for m in re.finditer(pat, lowered):
                s_char, e_char = m.start(), m.end()
                # map to token indices
                start_tok = None
                end_tok = None
                for i, (ts, te) in enumerate(offsets):
                    if ts <= s_char < te:
                        start_tok = i
                    if ts < e_char <= te:
                        end_tok = i + 1
                if start_tok is not None and end_tok is not None and st
                    spans.append((start_tok, end_tok, label))
        return spans


    def auto_label_text(text: str):
        """
        Return tokens, tags (BIO) for one job description using simple
        """
        # simple tokenization
        # keep punctuation as separate tokens
        tokens = re.findall(r"\w+|\S", text)
        if not tokens:
            return [], []

        lower_tokens = [t.lower() for t in tokens]
        spans = []

        # Programming languages
```

```
        spans += find_span_matches(lower_tokens, PROGRAMMING_LANGS, "PR

        # Frameworks
        spans += find_span_matches(lower_tokens, FRAMEWORKS, "FRAMEWORK

        # Tools (multi-word handled by split)
        spans += find_span_matches(lower_tokens, TOOLS, "TOOL")

        # Skill_tech
        spans += find_span_matches(lower_tokens, SKILL_TECH, "SKILL_TEC

        # Employment type (regex-ish phrase match)
        spans += find_span_matches(lower_tokens, EMPLOYMENT_TYPE_PATTER

        # Education level
        spans += find_regex_spans(text, tokens, "EDUCATION_LEVEL", EDU_

        # Degree major
        spans += find_span_matches(lower_tokens, DEGREE_MAJOR_PATTERNS,

        # Remote / onsite as LOCATION
        for i, tok in enumerate(lower_tokens):
            if tok in {"remote", "remotely"}:
                spans.append((i, i+1, "LOCATION"))

        # --- Improved JOB_TITLE heuristic ---
        n = len(tokens)
        for i, tok in enumerate(lower_tokens):
            if tok in JOB_HEAD_NOUNS:
                # expand left and right around head noun
                start = i
                end = i + 1

                # expand left while previous is an allowed modifier/con
                while start > 0:
                    prev = lower_tokens[start - 1]
                    # stop if punctuation or preposition that usually e
                    if tokens[start - 1] in {",", ".", ";", ":", "(", "
                        break
                    if prev in JOB_MODIFIERS or prev in JOB_CONTEXT_WOR
                        start -= 1
                    else:
                        break

                # expand right for context words (e.g., "developer lead
                while end < n:
                    nxt = lower_tokens[end]
                    if tokens[end] in {",", ".", ";", ":", "(", ")"}:
```

```
                    break
                if nxt in JOB_CONTEXT_WORDS:
                    end += 1
                else:
                    break

            if end > start:
                spans.append((start, end, "JOB_TITLE"))

        # --- Improved COMPANY heuristic ---
        tech_words = PROGRAMMING_LANGS | FRAMEWORKS | TOOLS | SKILL_TEC
        preps = {"at", "for", "with", "by", "join", "joining"}

        for i, tok in enumerate(lower_tokens):
            if tok in preps and i + 1 < n:
                start = i + 1
                j = start
                # collect capitalized tokens that are not tech or job w
                while j < n:
                    word = tokens[j]
                    low = lower_tokens[j]
                    if word in {",", ".", ";", ":", "(", ")", "-", "—"}
                        break
                    # stop if typical boundary word
                    if low in {"in", "on", "from"}:
                        break
                    # only keep if looks like a name (capitalized or al
                    if not (word[0].isupper() or word.isupper()):
                        break
                    # skip obvious non-company words
                    if low in COMPANY_STOPWORDS:
                        break
                    if low in JOB_HEAD_NOUNS or low in JOB_CONTEXT_WORD
                        break
                    if low in tech_words:
                        break
                    j += 1

                if j > start:
                    spans.append((start, j, "COMPANY"))

        # Remove overlaps (keep longer spans, then earlier ones)
        spans = sorted(spans, key=lambda x: (x[0], -(x[1] - x[0])))
        final_spans = []
        occupied = [False] * len(tokens)
        for s, e, lab in spans:
            if any(occupied[k] for k in range(s, e)):
                continue
```

```
            final_spans.append((s, e, lab))
            for k in range(s, e):
                occupied[k] = True

    # Build BIO tags
    tags = ["O"] * len(tokens)
    for s, e, lab in final_spans:
        tags[s] = f"B-{lab}"
        for k in range(s+1, e):
            tags[k] = f"I-{lab}"

    return tokens, tags


def main():
    print("Loading dataset...")
    ds = load_dataset("lang-uk/recruitment-dataset-job-descriptions

    if NUM_SAMPLES is None:
        texts = ds[TEXT_COL]
    else:
        texts = ds[TEXT_COL][:NUM_SAMPLES]
    print(f"Annotating {len(texts)} samples...")

    with open(OUTPUT_CONLL, "w", encoding="utf-8") as f:
        for text in texts:
            if text is None:
                continue
            tokens, tags = auto_label_text(text)
            if not tokens:
                continue
            for tok, tag in zip(tokens, tags):
                f.write(f"{tok} {tag}\n")
            f.write("\n")

    print(f"Saved auto-labeled BIO data to {OUTPUT_CONLL}")


if __name__ == "__main__":
    main()
```

```
Loading dataset...
Annotating 141897 samples...
Saved auto-labeled BIO data to data/auto_ner.conll
```

```
# Quick check: show first 40 lines of the generated BIO file
from itertools import islice

path = "data/auto_ner.conll"

with open(path, "r", encoding="utf-8") as f:
    for line in islice(f, 40):
        print(line.rstrip())
```

```
* O
Requirements O
* O
We O
' O
re O
looking O
for O
a O
long O
term O
collaboration O
with O
someone O
that O
has O
an O
experience O
in O
crypto O
, O
masternodes O
, O
nodes O
, O
validators O
etc O
. O
We O
need O
to O
set O
up O
: O
Kyber O
Network O
Nebulas O
SecretNetwork O
Tron O
Aion O
```

```
def read_conll(path):
```

```
def read_conll(path):
    """
    Reads a CoNLL/BIO file with format:
    token TAG
    ...
    (blank line between sentences)
    Returns: list_of_tokens, list_of_tags
    """
    sentences_tokens = []
    sentences_tags = []
    tokens, tags = [], []

    with open(path, "r", encoding="utf-8") as f:
        for line in f:
            line = line.strip()

            # sentence boundary
            if not line:
                if tokens:
                    sentences_tokens.append(tokens)
                    sentences_tags.append(tags)
                    tokens, tags = [], []
                continue

            parts = line.split()
            if len(parts) < 2:
                continue

            token = parts[0]
            tag = parts[-1]

            tokens.append(token)
            tags.append(tag)

    if tokens:
        sentences_tokens.append(tokens)
        sentences_tags.append(tags)

    return sentences_tokens, sentences_tags

tokens_list, tags_list = read_conll("data/auto_ner.conll")
len(tokens_list), tokens_list[0][:10], tags_list[0][:10]
```

```
(141897,
 ['*', 'Requirements', '*', 'We', "'", 're', 'looking', 'for', 'a',
'long'],
 ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O'])
```

```
from sklearn.model_selection import train_test_split
from datasets import Dataset, DatasetDict
from transformers import (
    AutoTokenizer,
    AutoModelForTokenClassification,
    DataCollatorForTokenClassification,
    TrainingArguments,
    Trainer,
)
import numpy as np
from seqeval.metrics import classification_report, f1_score

MODEL_NAME = "distilbert-base-uncased"

MAX_SENTENCES = 10000   # or 10000, etc.

tokens_small = tokens_list[:MAX_SENTENCES]
tags_small   = tags_list[:MAX_SENTENCES]

# Split into train/validation
train_tokens, val_tokens, train_tags, val_tags = train_test_split(
    tokens_small, tags_small, test_size=0.1, random_state=42
)

train_dataset = Dataset.from_dict({"tokens": train_tokens, "tags":
val_dataset = Dataset.from_dict({"tokens": val_tokens, "tags": val_
datasets_conll = DatasetDict({"train": train_dataset, "validation":

# Build label list from what actually appears in the file
all_tags = sorted({tag for sent in tags_list for tag in sent})
label_list = all_tags
num_labels = len(label_list)
label2id = {l: i for i, l in enumerate(label_list)}
id2label = {i: l for l, i in label2id.items()}

print("Labels:", label_list)

tokenizer = AutoTokenizer.from_pretrained(MODEL_NAME)

def tokenize_and_align_labels(examples):
    tokenized = tokenizer(
        examples["tokens"],
        is_split_into_words=True,
        truncation=True,
    )

    all_labels = examples["tags"]
```

```
        new_labels = []

        for i, labels in enumerate(all_labels):
            word_ids = tokenized.word_ids(batch_index=i)
            previous_word_idx = None
            label_ids = []

            for word_idx in word_ids:
                if word_idx is None:
                    # This token (like [CLS], [SEP]) should be ignored
                    label_ids.append(-100)
                else:
                    label = labels[word_idx]
                    #IMPORTANT CHANGE: do NOT convert B- to I-
                    # Just reuse the same label for all subtokens of a
                    label_ids.append(label2id[label])
                    previous_word_idx = word_idx

            new_labels.append(label_ids)

        tokenized["labels"] = new_labels
        return tokenized

    # re-create tokenized_datasets with the new function
    tokenized_datasets = datasets_conll.map(
        tokenize_and_align_labels,
        batched=True,
        remove_columns=["tokens", "tags"],
    )


    model = AutoModelForTokenClassification.from_pretrained(
        MODEL_NAME,
        num_labels=num_labels,
        id2label=id2label,
        label2id=label2id,
    )

    data_collator = DataCollatorForTokenClassification(tokenizer=tokeni

    def compute_metrics(p):
        predictions, labels = p
        predictions = np.argmax(predictions, axis=-1)

        true_labels = []
        true_preds = []

        for pred, lab in zip(predictions, labels):
```

```
            curr_true, curr_pred = [], []
            for p_id, l_id in zip(pred, lab):
                if l_id == -100:
                    continue
                curr_true.append(id2label[l_id])
                curr_pred.append(id2label[p_id])
            true_labels.append(curr_true)
            true_preds.append(curr_pred)

        return {"f1": f1_score(true_labels, true_preds)}

    import os
    os.environ["WANDB_DISABLED"] = "true"


    training_args = TrainingArguments(
        output_dir="ner_model",
        eval_strategy="epoch",
        save_strategy="epoch",
        learning_rate=5e-5,
        per_device_train_batch_size=8,
        per_device_eval_batch_size=8,
        num_train_epochs=8,
        weight_decay=0.01,
        logging_steps=20,
        load_best_model_at_end=True,
        metric_for_best_model="f1",
        greater_is_better=True,
    )

    trainer = Trainer(
        model=model,
        args=training_args,
        train_dataset=tokenized_datasets["train"],
        eval_dataset=tokenized_datasets["validation"],
        tokenizer=tokenizer,
        data_collator=data_collator,
        compute_metrics=compute_metrics,
    )

    trainer.train()
```

```
Labels: ['B-COMPANY', 'B-DEGREE_MAJOR', 'B-EDUCATION_LEVEL', 'B-EMPL
Map: 100%                                  9000/9000 [00:33<00:00, 307.09 examples/
                                           s]

Map: 100%                                  1000/1000 [00:02<00:00, 391.24 examples/
```

s]

```
Some weights of DistilBertForTokenClassification were not initialize
You should probably TRAIN this model on a down-stream task to be abl
Using the `WANDB_DISABLED` environment variable is deprecated and wi
/tmp/ipython-input-1678497816.py:126: FutureWarning: `tokenizer` is
  trainer = Trainer(
```

[9000/9000 1:01:59, Epoch 8/8]

| Epoch | Training Loss | Validation Loss | F1 |
|---|---|---|---|
| 1 | 0.006600 | 0.007371 | 0.972598 |
| 2 | 0.005000 | 0.006345 | 0.980071 |
| 3 | 0.004300 | 0.005589 | 0.981681 |
| 4 | 0.003300 | 0.006212 | 0.980438 |
| 5 | 0.002300 | 0.006053 | 0.982105 |
| 6 | 0.001300 | 0.007216 | 0.983685 |
| 7 | 0.000500 | 0.007642 | 0.983378 |
| 8 | 0.000600 | 0.008445 | 0.984147 |

```
TrainOutput(global_step=9000, training_loss=0.006880088910615693,
metrics={'train_runtime': 3719.3842, 'train_samples_per_second':
19.358, 'train_steps_per_second': 2.42, 'total_flos':
9128042051609856.0, 'train_loss': 0.006880088910615693, 'epoch':
8.0})
```

```
predictions, labels, _ = trainer.predict(tokenized_datasets["valida
pred_labels = np.argmax(predictions, axis=-1)

true_labels = []
true_preds = []

for pred, lab in zip(pred_labels, labels):
    curr_true, curr_pred = [], []
    for p_id, l_id in zip(pred, lab):
        if l_id == -100:
            continue
        curr_true.append(id2label[l_id])
        curr_pred.append(id2label[p_id])
    true_labels.append(curr_true)
    true_preds.append(curr_pred)

print(classification_report(true_labels, true_preds))
```

```
                    precision    recall  f1-score   support

           COMPANY       0.89      0.88      0.88      1754
      DEGREE_MAJOR       1.00      1.00      1.00       721
   EDUCATION_LEVEL       1.00      0.97      0.98        92
  EMPLOYEMENT_TYPE       0.99      1.00      0.99        79
         FRAMEWORK       1.00      1.00      1.00      1053
         JOB_TITLE       1.00      1.00      1.00      1531
          LOCATION       1.00      1.00      1.00       348
PROGRAMMING_LANGUAGE       1.00      1.00      1.00      2436
        SKILL_TECH       1.00      1.00      1.00      1753
              TOOL       1.00      1.00      1.00      4451

         micro avg       0.98      0.98      0.98     14218
         macro avg       0.99      0.98      0.99     14218
      weighted avg       0.98      0.98      0.98     14218
```

```
import torch

model.eval()

def predict_entities(text: str):
    device = next(model.parameters()).device

    words = text.split()
    encoding = tokenizer(
        words,
        is_split_into_words=True,
```

```
        return_tensors="pt",
        truncation=True,
    )
    encoding = {k: v.to(device) for k, v in encoding.items()}

    with torch.no_grad():
        outputs = model(**encoding)

    logits = outputs.logits
    preds = logits.argmax(dim=-1)[0].tolist()
    tokens = tokenizer.convert_ids_to_tokens(encoding["input_ids"][

    entities = []
    current = None

    for token, pred_id in zip(tokens, preds):
        if token in ["[CLS]", "[SEP]", "[PAD]"]:
            continue

        label = id2label[pred_id]

        if label == "O":
            if current:
                entities.append(current)
                current = None
            continue

        # label like "B-TOOL", "I-FRAMEWORK"
        tag, ent_type = label.split("-", 1)
        is_subword = token.startswith("##")
        piece = token[2:] if is_subword else token

        if tag == "B" or (current and current["type"] != ent_type):
            # start a new entity
            if current:
                entities.append(current)
            current = {"type": ent_type, "text": piece}
        else:  # tag == "I"
            if current is None:
                # model gave I-* without prior B-*, start new entit
                current = {"type": ent_type, "text": piece}
            else:
                if is_subword:
                    current["text"] += piece      # join subword w/
                else:
                    current["text"] += " " + piece

    if current:
```

```
            entities.append(current)

        return entities

    sample_jd = """
    UI/UX Designer required to create interactive web and mobile interf
    designs. Must be proficient in Figma, design systems, wireframing,
    prototyping, and user-flow mapping. Preferred experience in usabili
     testing and heuristic evaluation. Remote role at Zomato.
    """

    predict_entities(sample_jd)
```

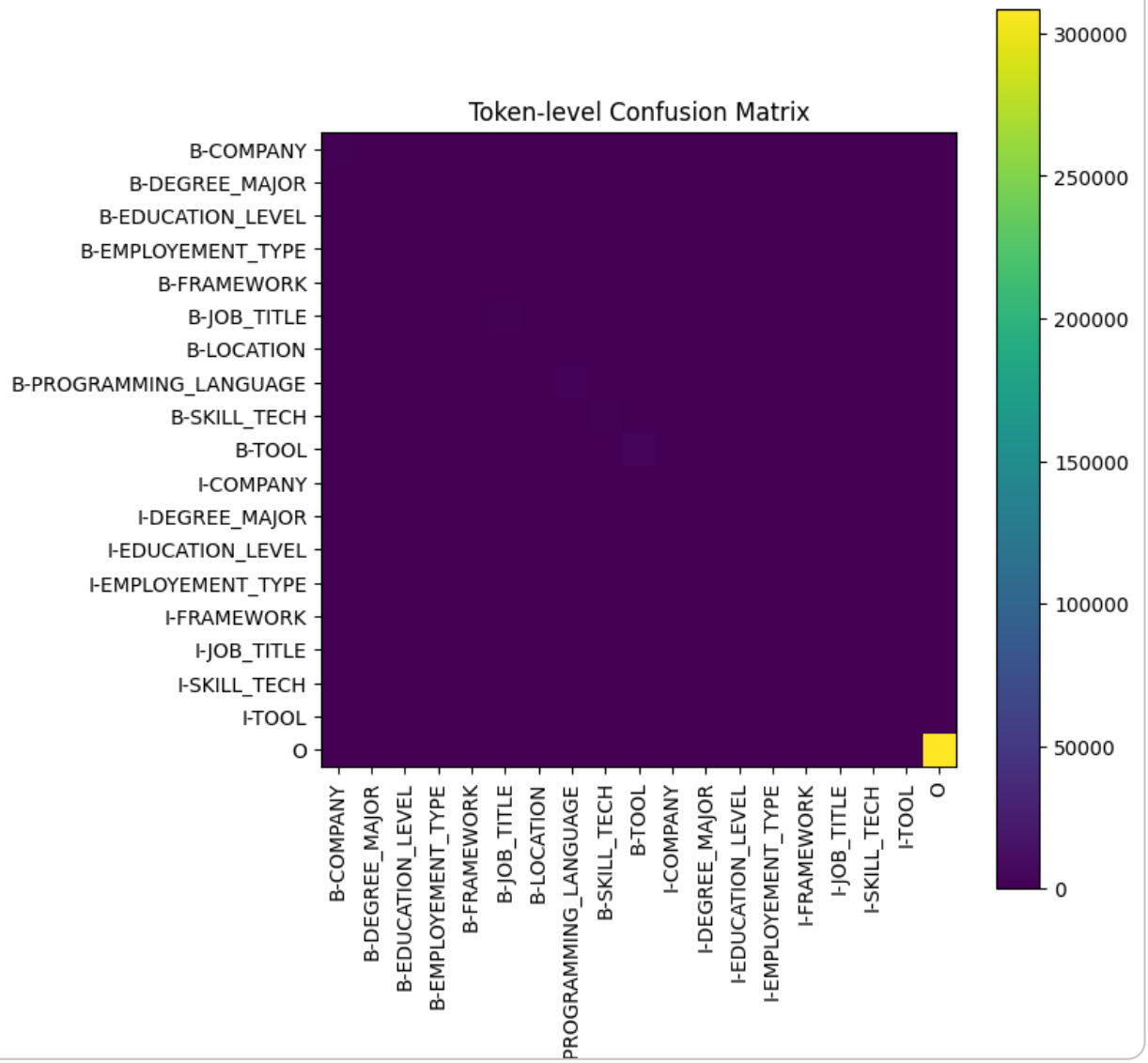
```
[{'type': 'JOB_TITLE', 'text': 'designer'},
 {'type': 'LOCATION', 'text': 'remote'},
 {'type': 'COMPANY', 'text': 'z'},
 {'type': 'COMPANY', 'text': 'oma'},
 {'type': 'COMPANY', 'text': 'to'}]
```

```
import numpy as np
from sklearn.metrics import accuracy_score, f1_score as sk_f1_score

predictions, labels, _ = trainer.predict(tokenized_datasets["valida
pred_labels = np.argmax(predictions, axis=-1)

flat_true = []
flat_pred = []

for pred, lab in zip(pred_labels, labels):
    for p_id, l_id in zip(pred, lab):
        if l_id == -100:
            continue
        flat_true.append(l_id)
        flat_pred.append(p_id)

token_acc = accuracy_score(flat_true, flat_pred)
token_f1  = sk_f1_score(flat_true, flat_pred, average="macro")

print("Token-level accuracy:", token_acc)
print("Token-level macro F1:", token_f1)
```

```
Token-level accuracy: 0.9985083891529318
Token-level macro F1: 0.9782727591200416
```

```
#this iss then Confusion matrix (which labels get confused)
from sklearn.metrics import confusion_matrix
```

```
import matplotlib.pyplot as plt
import numpy as np

cm = confusion_matrix(flat_true, flat_pred, labels=list(id2label

label_names = [id2label[i] for i in id2label.keys()]

fig, ax = plt.subplots(figsize=(8, 8))
im = ax.imshow(cm, interpolation="nearest")
ax.set_title("Token-level Confusion Matrix")
ax.set_xticks(np.arange(len(label_names)))
ax.set_yticks(np.arange(len(label_names)))
ax.set_xticklabels(label_names, rotation=90)
ax.set_yticklabels(label_names)
plt.colorbar(im, ax=ax)

plt.tight_layout()
plt.show()
```

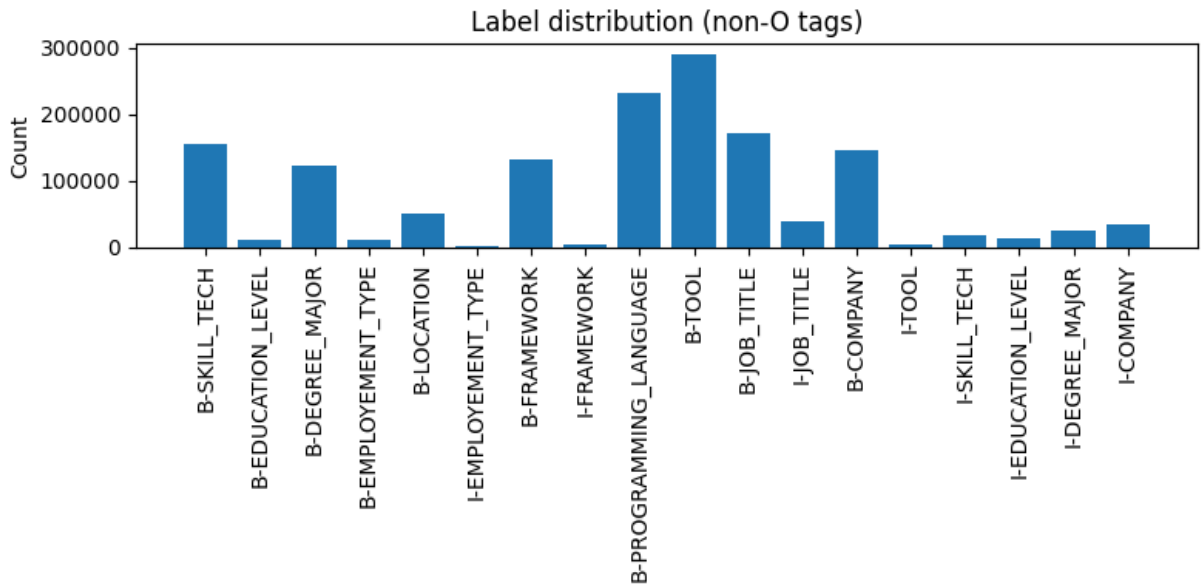


```
#here is then “Most wrong” sentences (qualitative error analysis
# Build per-sentence error counts
errors_per_sent = []

for sent_idx, (pred, lab) in enumerate(zip(pred_labels, labels)):
    sent_errors = 0
    total = 0
    for p_id, l_id in zip(pred, lab):
        if l_id == -100:
            continue
        total += 1
        if p_id != l_id:
            sent_errors += 1
    if total > 0:
        errors_per_sent.append((sent_idx, sent_errors, total))

# sort by error rate
errors_per_sent.sort(key=lambda x: x[1]/x[2], reverse=True)

# Show top 5 worst sentences
for idx, err, tot in errors_per_sent[:5]:
    print(f"\nSentence {idx} — errors {err}/{tot}")
    print("Tokens: ", tokens_list[idx])
    print("True : ", true_labels[idx])
    print("Pred : ", true_preds[idx])
```

```
Sentence 613 — errors 3/86
Tokens:  ['Our', 'company', 'participates', 'in', 'developing', 'a',
True :  ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'B-P
Pred :  ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'B-P

Sentence 700 — errors 6/187
Tokens:  ['Kameron', ',', 'a', 'company', 'specializing', 'in', 'eCo
True :  ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O',
Pred :  ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O',

Sentence 388 — errors 6/197
Tokens:  ['*', '*', 'A', '-', 'LISTWARE', 'is', 'looking', 'for', 'a
True :  ['O', 'O', 'O', 'O', 'B-JOB_TITLE', 'O', 'O', 'O', 'O', 'O',
Pred :  ['O', 'O', 'O', 'O', 'B-JOB_TITLE', 'O', 'O', 'O', 'O', 'O',

Sentence 2 — errors 3/105
Tokens:  ['*', '*', 'Product', '*', '*', 'The', 'product', 'is', 'a'
True :  ['O', 'O', 'O', 'O', 'B-COMPANY', 'B-JOB_TITLE', 'O', 'O', '
Pred :  ['O', 'O', 'O', 'O', 'B-COMPANY', 'B-JOB_TITLE', 'O', 'O', '

Sentence 537 — errors 4/144
```

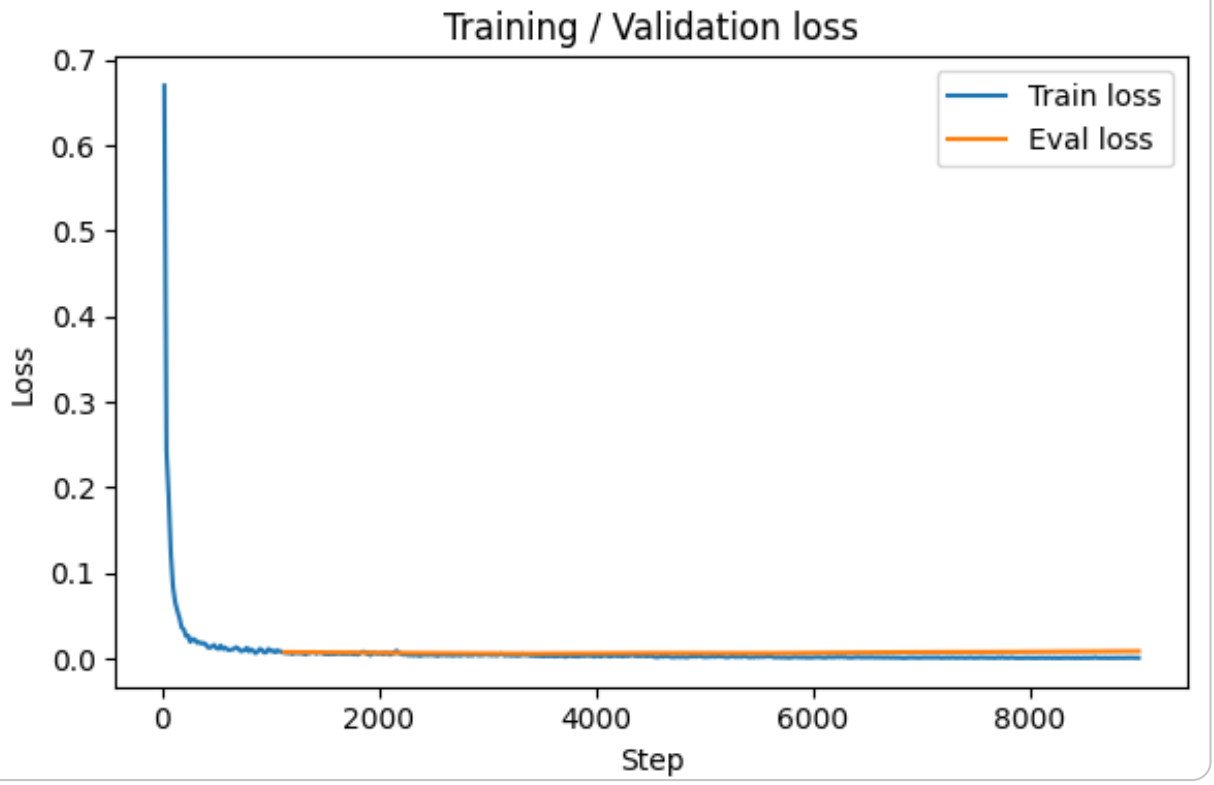
```
Tokens:  ['Job', 'Summary', ':', 'Far', 'beyond', 'today', '’', 's',
True :  ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O',
Pred :  ['O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O', 'O',
```

```
#Label distribution bar plot (from our dataset)
import collections
import matplotlib.pyplot as plt

label_counts = collections.Counter()

for tags in tags_list:
    for tag in tags:
        if tag != "O":
            label_counts[tag] += 1

labels = list(label_counts.keys())
counts = [label_counts[l] for l in labels]

plt.figure(figsize=(8,4))
plt.bar(labels, counts)
plt.xticks(rotation=90)
plt.title("Label distribution (non-O tags)")
plt.ylabel("Count")
plt.tight_layout()
plt.show()
```




```
#HuggingFace Trainer logs to trainer.state.log_history.
#Loss curve = great “learning curve” slide.
import matplotlib.pyplot as plt

logs = trainer.state.log_history
```

```
logs = trainer.state.log_history

train_steps = []
train_losses = []
eval_steps = []
eval_losses = []

for entry in logs:
    if "loss" in entry and "epoch" in entry and "eval_loss" not
        train_steps.append(entry["step"])
        train_losses.append(entry["loss"])
    if "eval_loss" in entry:
        eval_steps.append(entry["step"])
        eval_losses.append(entry["eval_loss"])

plt.figure(figsize=(6,4))
plt.plot(train_steps, train_losses, label="Train loss")
if eval_losses:
    plt.plot(eval_steps, eval_losses, label="Eval loss")
plt.xlabel("Step")
plt.ylabel("Loss")
plt.title("Training / Validation loss")
plt.legend()
plt.tight_layout()
plt.show()
```



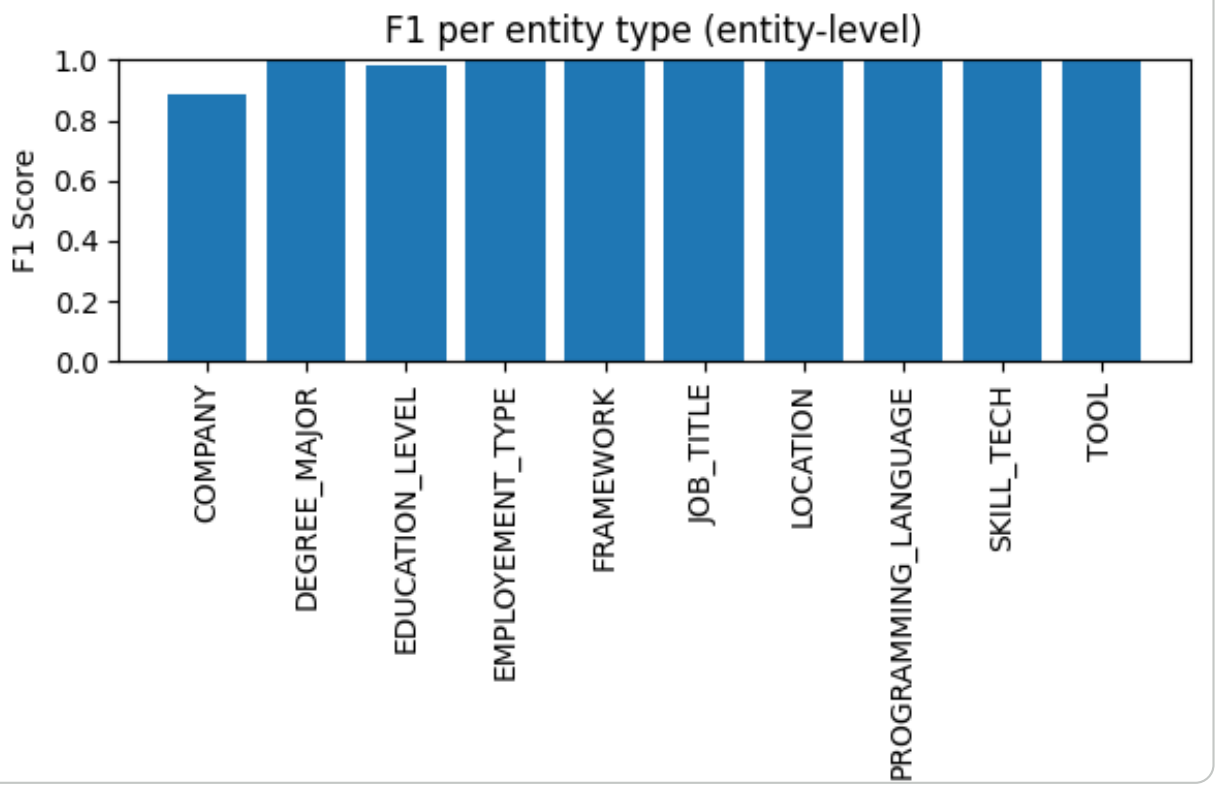

```
from seqeval.metrics import classification_report
```

```
report = classification_report(true_labels, true_preds, output_c
report
```

```
{'COMPANY': {'precision': np.float64(0.8888248847926268),
  'recall': np.float64(0.8797035347776511),
  'f1-score': np.float64(0.8842406876790831),
  'support': np.int64(1754)},
 'DEGREE_MAJOR': {'precision': np.float64(1.0),
  'recall': np.float64(1.0),
  'f1-score': np.float64(1.0),
  'support': np.int64(721)},
 'EDUCATION_LEVEL': {'precision': np.float64(1.0),
  'recall': np.float64(0.967391304347826),
  'f1-score': np.float64(0.9834254143646408),
  'support': np.int64(92)},
 'EMPLOYEMENT_TYPE': {'precision': np.float64(0.9875),
  'recall': np.float64(1.0),
  'f1-score': np.float64(0.9937106918238994),
  'support': np.int64(79)},
 'FRAMEWORK': {'precision': np.float64(0.995274102079395),
  'recall': np.float64(1.0),
  'f1-score': np.float64(0.9976314542870678),
  'support': np.int64(1053)},
 'JOB_TITLE': {'precision': np.float64(0.9980379332897319),
  'recall': np.float64(0.9967341606792945),
  'f1-score': np.float64(0.9973856209150327),
  'support': np.int64(1531)},
 'LOCATION': {'precision': np.float64(0.997134670487106),
  'recall': np.float64(1.0),
  'f1-score': np.float64(0.9985652797704447),
  'support': np.int64(348)},
 'PROGRAMMING_LANGUAGE': {'precision':
np.float64(0.9995896594173164),
  'recall': np.float64(1.0),
  'f1-score': np.float64(0.9997947876051714),
  'support': np.int64(2436)},
 'SKILL_TECH': {'precision': np.float64(0.9965889710062535),
  'recall': np.float64(1.0),
  'f1-score': np.float64(0.9982915717539863),
  'support': np.int64(1753)},
 'TOOL': {'precision': np.float64(0.9950816007154035),
  'recall': np.float64(1.0),
  'f1-score': np.float64(0.9975347377857463),
  'support': np.int64(4451)},
 'micro avg': {'precision': np.float64(0.9836975616611623),
  'recall': np.float64(0.9845969897313265),
  'f1-score': np.float64(0.984147070195789),
  'support': np.int64(14218)},
 'macro avg': {'precision': np.float64(0.9858031821787833),
  'recall': np.float64(0.9843828999804772),
  'f1-score': np.float64(0.9850580245985073),
```

```
  'support': np.int64(14218)},
 'weighted avg': {'precision': np.float64(0.983553453362693),
  'recall': np.float64(0.9845969897313265),
  'f1-score': np.float64(0.984067577654055),
  'support': np.int64(14218)}}
```

```
import matplotlib.pyplot as plt

entity_labels = []
f1s = []

for k, v in report.items():
    if k in {"micro avg", "macro avg", "weighted avg"}:
        continue
    entity_labels.append(k)
    f1s.append(v["f1-score"])

plt.figure(figsize=(6,4))
plt.bar(entity_labels, f1s)
plt.xticks(rotation=90)
plt.ylabel("F1 Score")
plt.title("F1 per entity type (entity-level)")
plt.ylim(0,1)
plt.tight_layout()
plt.show()
```



```
def ner_on_job_description(text: str):
    """
    Returns list of entities and also a structured dict label -> [v
    """
    ents = predict_entities(text)

    by_type = {}
    for e in ents:
        by_type.setdefault(e["type"], []).append(e["text"])

    return ents, by_type
```

```
jd = "We are hiring a Senior Python Developer at Google in London.
ents, structured = ner_on_job_description(jd)
print("Entities:", ents)
print("Structured:", structured)
```

```
Entities: [{'type': 'PROGRAMMING_LANGUAGE', 'text': 'python'}, {'typ
Structured: {'PROGRAMMING_LANGUAGE': ['python'], 'JOB_TITLE': ['deve
```

```
import pandas as pd

def entities_to_row(text: str):
    _, by_type = ner_on_job_description(text)
    row = {
        "job_title": ", ".join(by_type.get("JOB_TITLE", [])),
        "company": ", ".join(by_type.get("COMPANY", [])),
        "location": ", ".join(by_type.get("LOCATION", [])),
        "languages": ", ".join(by_type.get("PROGRAMMING_LANGUAGE",
        "frameworks": ", ".join(by_type.get("FRAMEWORK", [])),
        "tools": ", ".join(by_type.get("TOOL", [])),
        "skills": ", ".join(by_type.get("SKILL_TECH", [])),
    }
    return row

examples = [
    "We are hiring a Senior Python Developer at Google in London. Y
    "Remote React Native Engineer for Facebook in New York. Experie
]

rows = [entities_to_row(t) for t in examples]
df = pd.DataFrame(rows)
df
```

| | job_title | company | location | languages | frameworks | tools | skills |
|---|---|---|---|---|---|---|---|
| 0 | developer | google | | python | react | aw, s | |
| 1 | engineer | facebook | remote | | react | dock, er | graph, q, l |

Next steps: Generate code with df | New interactive sheet

```
trainer.save_model("ner_model")
tokenizer.save_pretrained("ner_model")
```

```
('ner_model/tokenizer_config.json',
 'ner_model/special_tokens_map.json',
 'ner_model/vocab.txt',
 'ner_model/added_tokens.json',
 'ner_model/tokenizer.json')
```

```
%%writefile app.py
```

```
import streamlit as st
import torch
from transformers import AutoTokenizer, AutoModelForTokenClassifica

MODEL_DIR = "ner_model"  # or your output dir

@st.cache_resource
def load_model():
    tokenizer = AutoTokenizer.from_pretrained(MODEL_DIR)
    model = AutoModelForTokenClassification.from_pretrained(MODEL_D
    model.eval()
    device = torch.device("cuda" if torch.cuda.is_available() else
    model.to(device)
    id2label = model.config.id2label
    return tokenizer, model, id2label, device

tokenizer, model, id2label, device = load_model()

def predict_entities(text: str):
    words = text.split()
    encoding = tokenizer(words, is_split_into_words=True,
                         return_tensors="pt", truncation=True)
    encoding = {k: v.to(device) for k, v in encoding.items()}

    with torch.no_grad():
        outputs = model(**encoding)

    logits = outputs.logits
    preds = logits.argmax(dim=-1)[0].tolist()
    tokens = tokenizer.convert_ids_to_tokens(encoding["input_ids"][

    entities = []
    current = None

    for token, pred_id in zip(tokens, preds):
        if token in ["[CLS]", "[SEP]", "[PAD]"]:
            continue

        label = id2label[pred_id]
        if label == "O":
            if current:
                entities.append(current)
                current = None
            continue

        tag, ent_type = label.split("-", 1)
        is_subword = token.startswith("##")
        piece = token[2:] if is_subword else token
```

```
            if tag == "B" or (current and current["type"] != ent_type):
                if current:
                    entities.append(current)
                current = {"type": ent_type, "text": piece}
            else:
                if current is None:
                    current = {"type": ent_type, "text": piece}
                else:
                    if is_subword:
                        current["text"] += piece
                    else:
                        current["text"] += " " + piece

    if current:
        entities.append(current)
    return entities

st.title("Job Description NER Demo")

default_text = "We are hiring a Senior Python Developer at Google i
text = st.text_area("Paste a job description:", default_text, heigh

if st.button("Extract entities"):
    ents = predict_entities(text)
    st.write("### Extracted entities")
    for e in ents:
        st.write(f"**{e['type']}**: {e['text']}")
```

```
Overwriting app.py
```

```
!pip install pyngrok streamlit -q

from pyngrok import ngrok

# paste ONLY the raw token string between the quotes:
#ngrok.set_auth_token("YOUR_NEW_TOKEN_HERE")
```

```
ngrok.set_auth_token("363MF6W2a2DavrN4RMBWLBpxENV_2L6rt77zoAKPN
```

```
!streamlit run app.py &>/dev/null&
public_url = ngrok.connect(8501)
public_url
```

```
<NgrokTunnel: "https://marylyn-nonmakeup-maryjo.ngrok-free.dev" ->
"http://localhost:8501">
```