Sudan Crisis 5

July 11, 2025

Human Rights Monitoring and Protection of Population in Sudan Using Twitter Data

```
[1]: # Named Entity Recognition (NER) and Relation Extraction
     # Install Required Packages
     %pip install pandas transformers torch spacy networkx matplotlib
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Requirement already satisfied: pandas in
/home/hadoop/py311env/lib/python3.11/site-packages (2.2.3)
Requirement already satisfied: transformers in
/home/hadoop/py311env/lib/python3.11/site-packages (4.53.1)
Requirement already satisfied: torch in
/home/hadoop/py311env/lib/python3.11/site-packages (2.7.0)
Requirement already satisfied: spacy in
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Requirement already satisfied: networkx in
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Requirement already satisfied: matplotlib in
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Requirement already satisfied: numpy>=1.23.2 in
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Requirement already satisfied: python-dateutil>=2.8.2 in
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Requirement already satisfied: pytz>=2020.1 in
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Requirement already satisfied: tzdata>=2022.7 in
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Requirement already satisfied: filelock in
/home/hadoop/py311env/lib/python3.11/site-packages (from transformers) (3.18.0)
Requirement already satisfied: huggingface-hub<1.0,>=0.30.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from transformers) (0.32.3)
Requirement already satisfied: packaging>=20.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from transformers) (25.0)
Requirement already satisfied: pyyaml>=5.1 in
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Requirement already satisfied: regex!=2019.12.17 in
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Requirement already satisfied: requests in

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Requirement already satisfied: tokenizers<0.22,>=0.21 in
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Requirement already satisfied: fsspec>=2023.5.0 in
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Requirement already satisfied: hf-xet<2.0.0,>=1.1.2 in
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Requirement already satisfied: jinja2 in
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Requirement already satisfied: pydantic!=1.8,!=1.8.1,<3.0.0,>=1.7.4 in
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Requirement already satisfied: langcodes<4.0.0,>=3.2.0 in
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Requirement already satisfied: language-data>=1.2 in
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Requirement already satisfied: charset-normalizer<4,>=2 in
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(3.4.2)
Requirement already satisfied: idna<4,>=2.5 in
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(3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in
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(2.4.0)
Requirement already satisfied: certifi>=2017.4.17 in
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(2025.4.26)
Requirement already satisfied: blis<1.3.0,>=1.2.0 in
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thinc<8.4.0,>=8.3.4->spacy) (1.2.1)
Requirement already satisfied: confection<1.0.0,>=0.0.1 in
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thinc<8.4.0,>=8.3.4->spacy) (0.1.5)
Requirement already satisfied: click>=8.0.0 in
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typer<1.0.0,>=0.3.0->spacy) (1.5.4)
Requirement already satisfied: rich>=10.11.0 in
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Requirement already satisfied: smart-open<8.0.0,>=5.2.1 in
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Requirement already satisfied: wrapt in
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open<8.0.0,>=5.2.1->weasel<0.5.0,>=0.1.0->spacy) (1.14.1)
Requirement already satisfied: contourpy>=1.0.1 in
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Requirement already satisfied: cycler>=0.10 in
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Requirement already satisfied: fonttools>=4.22.0 in
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Requirement already satisfied: kiwisolver>=1.3.1 in
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Requirement already satisfied: pillow>=8 in
/home/hadoop/py311env/lib/python3.11/site-packages (from matplotlib) (11.2.1)
Requirement already satisfied: pyparsing>=2.3.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from matplotlib) (3.2.3)
Requirement already satisfied: marisa-trie>=1.1.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from language-
data>=1.2->langcodes<4.0.0,>=3.2.0->spacy) (1.2.1)
Requirement already satisfied: six>=1.5 in
/home/hadoop/py311env/lib/python3.11/site-packages (from python-
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dateutil>=2.8.2->pandas) (1.17.0)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
rich>=10.11.0->typer<1.0.0,>=0.3.0->spacy) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
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rich>=10.11.0->typer<1.0.0,>=0.3.0->spacy) (2.19.1)
Requirement already satisfied: mdurl~=0.1 in
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py>=2.2.0->rich>=10.11.0->typer<1.0.0,>=0.3.0->spacy) (0.1.2)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in
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(1.3.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from jinja2->torch) (3.0.2)
Note: you may need to restart the kernel to use updated packages.
```

[2]:
```
%pip install kafka-python pandas geopandas matplotlib seaborn nltk spacy torch␣
↪transformers pyspark findspark scikit-learn shapely geopy tensorflow==2.15.0␣
↪tensorflow-hub==0.15.0 tensorflow-text==2.15.0 keras==2.15.0 numpy
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Requirement already satisfied: kafka-python in
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Requirement already satisfied: pandas in
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Requirement already satisfied: geopandas in
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Requirement already satisfied: matplotlib in
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Requirement already satisfied: seaborn in
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Requirement already satisfied: nltk in
/home/hadoop/py311env/lib/python3.11/site-packages (3.9.1)
Requirement already satisfied: spacy in
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Requirement already satisfied: torch in
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Requirement already satisfied: transformers in
/home/hadoop/py311env/lib/python3.11/site-packages (4.53.1)
Requirement already satisfied: pyspark in
/home/hadoop/py311env/lib/python3.11/site-packages (4.0.0)
Requirement already satisfied: findspark in
/home/hadoop/py311env/lib/python3.11/site-packages (2.0.1)
Requirement already satisfied: scikit-learn in
/home/hadoop/py311env/lib/python3.11/site-packages (1.6.1)
Requirement already satisfied: shapely in
/home/hadoop/py311env/lib/python3.11/site-packages (2.1.1)
Requirement already satisfied: geopy in
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/home/hadoop/py311env/lib/python3.11/site-packages (2.4.1)
Requirement already satisfied: tensorflow==2.15.0 in
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Requirement already satisfied: tensorflow-hub==0.15.0 in
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Requirement already satisfied: tensorflow-text==2.15.0 in
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Requirement already satisfied: keras==2.15.0 in
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Requirement already satisfied: numpy in
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Requirement already satisfied: absl-py>=1.0.0 in
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(2.3.0)
Requirement already satisfied: astunparse>=1.6.0 in
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(1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in
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Requirement already satisfied: gast!=0.5.0,!=0.5.1,!=0.5.2,>=0.2.1 in
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Requirement already satisfied: h5py>=2.9.0 in
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(18.1.1)
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Requirement already satisfied: opt-einsum>=2.3.2 in
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Requirement already satisfied: packaging in
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(25.0)
Requirement already satisfied:
protobuf!=4.21.0,!=4.21.1,!=4.21.2,!=4.21.3,!=4.21.4,!=4.21.5,<5.0.0dev,>=3.20.3
in /home/hadoop/py311env/lib/python3.11/site-packages (from tensorflow==2.15.0)
(4.25.8)
Requirement already satisfied: setuptools in
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(65.5.0)

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Requirement already satisfied: six>=1.12.0 in
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(1.17.0)
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Requirement already satisfied: wrapt<1.15,>=1.11.0 in
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(1.14.1)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in
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Requirement already satisfied: grpcio<2.0,>=1.24.3 in
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(1.71.0)
Requirement already satisfied: tensorboard<2.16,>=2.15 in
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(2.15.2)
Requirement already satisfied: tensorflow-estimator<2.16,>=2.15.0 in
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(2.15.0)
Requirement already satisfied: google-auth<3,>=1.6.3 in
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tensorboard<2.16,>=2.15->tensorflow==2.15.0) (2.40.3)
Requirement already satisfied: google-auth-oauthlib<2,>=0.5 in
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tensorboard<2.16,>=2.15->tensorflow==2.15.0) (1.2.2)
Requirement already satisfied: markdown>=2.6.8 in
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Requirement already satisfied: requests<3,>=2.21.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
tensorboard<2.16,>=2.15->tensorflow==2.15.0) (2.32.3)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in
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Requirement already satisfied: werkzeug>=1.0.1 in
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tensorboard<2.16,>=2.15->tensorflow==2.15.0) (3.1.3)
Requirement already satisfied: cachetools<6.0,>=2.0.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from google-
auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (5.5.2)
Requirement already satisfied: pyasn1-modules>=0.2.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from google-
auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (0.4.2)
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Requirement already satisfied: rsa<5,>=3.1.4 in
/home/hadoop/py311env/lib/python3.11/site-packages (from google-
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/home/hadoop/py311env/lib/python3.11/site-packages (from google-auth-
oauthlib<2,>=0.5->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (2.0.0)
Requirement already satisfied: charset-normalizer<4,>=2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (3.4.2)
Requirement already satisfied: idna<4,>=2.5 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (3.10)
Requirement already satisfied: urllib3<3,>=1.21.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (2.4.0)
Requirement already satisfied: certifi>=2017.4.17 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
requests<3,>=2.21.0->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (2025.4.26)
Requirement already satisfied: pyasn1>=0.1.3 in
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auth<3,>=1.6.3->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (0.6.1)
Requirement already satisfied: python-dateutil>=2.8.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from pandas) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from pandas) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in
/home/hadoop/py311env/lib/python3.11/site-packages (from pandas) (2025.2)
Requirement already satisfied: pyogrio>=0.7.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from geopandas) (0.11.0)
Requirement already satisfied: pyproj>=3.3.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from geopandas) (3.7.1)
Requirement already satisfied: contourpy>=1.0.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from matplotlib) (1.3.2)
Requirement already satisfied: cycler>=0.10 in
/home/hadoop/py311env/lib/python3.11/site-packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from matplotlib) (4.58.1)
Requirement already satisfied: kiwisolver>=1.3.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from matplotlib) (1.4.8)
Requirement already satisfied: pillow>=8 in
/home/hadoop/py311env/lib/python3.11/site-packages (from matplotlib) (11.2.1)
Requirement already satisfied: pyparsing>=2.3.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from matplotlib) (3.2.3)
Requirement already satisfied: click in
/home/hadoop/py311env/lib/python3.11/site-packages (from nltk) (8.2.1)
Requirement already satisfied: joblib in
/home/hadoop/py311env/lib/python3.11/site-packages (from nltk) (1.5.1)
Requirement already satisfied: regex>=2021.8.3 in

/home/hadoop/py311env/lib/python3.11/site-packages (from nltk) (2024.11.6)
Requirement already satisfied: tqdm in
/home/hadoop/py311env/lib/python3.11/site-packages (from nltk) (4.67.1)
Requirement already satisfied: spacy-legacy<3.1.0,>=3.0.11 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (3.0.12)
Requirement already satisfied: spacy-loggers<2.0.0,>=1.0.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (1.0.5)
Requirement already satisfied: murmurhash<1.1.0,>=0.28.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (1.0.13)
Requirement already satisfied: cymem<2.1.0,>=2.0.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (2.0.11)
Requirement already satisfied: preshed<3.1.0,>=3.0.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (3.0.10)
Requirement already satisfied: thinc<8.4.0,>=8.3.4 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (8.3.4)
Requirement already satisfied: wasabi<1.2.0,>=0.9.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (1.1.3)
Requirement already satisfied: srsly<3.0.0,>=2.4.3 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (2.5.1)
Requirement already satisfied: catalogue<2.1.0,>=2.0.6 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (2.0.10)
Requirement already satisfied: weasel<0.5.0,>=0.1.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (0.4.1)
Requirement already satisfied: typer<1.0.0,>=0.3.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (0.16.0)
Requirement already satisfied: pydantic!=1.8,!=1.8.1,<3.0.0,>=1.7.4 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (2.11.5)
Requirement already satisfied: jinja2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (3.1.6)
Requirement already satisfied: langcodes<4.0.0,>=3.2.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from spacy) (3.5.0)
Requirement already satisfied: language-data>=1.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
langcodes<4.0.0,>=3.2.0->spacy) (1.3.0)
Requirement already satisfied: annotated-types>=0.6.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
pydantic!=1.8,!=1.8.1,<3.0.0,>=1.7.4->spacy) (0.7.0)
Requirement already satisfied: pydantic-core==2.33.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
pydantic!=1.8,!=1.8.1,<3.0.0,>=1.7.4->spacy) (2.33.2)
Requirement already satisfied: typing-inspection>=0.4.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
pydantic!=1.8,!=1.8.1,<3.0.0,>=1.7.4->spacy) (0.4.1)
Requirement already satisfied: blis<1.3.0,>=1.2.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
thinc<8.4.0,>=8.3.4->spacy) (1.2.1)
Requirement already satisfied: confection<1.0.0,>=0.0.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from

thinc<8.4.0,>=8.3.4->spacy) (0.1.5)
Requirement already satisfied: shellingham>=1.3.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
typer<1.0.0,>=0.3.0->spacy) (1.5.4)
Requirement already satisfied: rich>=10.11.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
typer<1.0.0,>=0.3.0->spacy) (14.0.0)
Requirement already satisfied: cloudpathlib<1.0.0,>=0.7.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
weasel<0.5.0,>=0.1.0->spacy) (0.21.1)
Requirement already satisfied: smart-open<8.0.0,>=5.2.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
weasel<0.5.0,>=0.1.0->spacy) (7.1.0)
Requirement already satisfied: filelock in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (3.18.0)
Requirement already satisfied: sympy>=1.13.3 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (1.14.0)
Requirement already satisfied: networkx in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (3.5)
Requirement already satisfied: fsspec in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (2025.3.0)
Requirement already satisfied: nvidia-cuda-nvrtc-cu12==12.6.77 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (12.6.77)
Requirement already satisfied: nvidia-cuda-runtime-cu12==12.6.77 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (12.6.77)
Requirement already satisfied: nvidia-cuda-cupti-cu12==12.6.80 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (12.6.80)
Requirement already satisfied: nvidia-cudnn-cu12==9.5.1.17 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (9.5.1.17)
Requirement already satisfied: nvidia-cublas-cu12==12.6.4.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (12.6.4.1)
Requirement already satisfied: nvidia-cufft-cu12==11.3.0.4 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (11.3.0.4)
Requirement already satisfied: nvidia-curand-cu12==10.3.7.77 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (10.3.7.77)
Requirement already satisfied: nvidia-cusolver-cu12==11.7.1.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (11.7.1.2)
Requirement already satisfied: nvidia-cusparse-cu12==12.5.4.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (12.5.4.2)
Requirement already satisfied: nvidia-cusparselt-cu12==0.6.3 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (0.6.3)
Requirement already satisfied: nvidia-nccl-cu12==2.26.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (2.26.2)
Requirement already satisfied: nvidia-nvtx-cu12==12.6.77 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (12.6.77)
Requirement already satisfied: nvidia-nvjitlink-cu12==12.6.85 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (12.6.85)
Requirement already satisfied: nvidia-cufile-cu12==1.11.1.6 in

/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (1.11.1.6)
Requirement already satisfied: triton==3.3.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch) (3.3.0)
Requirement already satisfied: huggingface-hub<1.0,>=0.30.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from transformers) (0.32.3)
Requirement already satisfied: pyyaml>=5.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from transformers) (6.0.2)
Requirement already satisfied: tokenizers<0.22,>=0.21 in
/home/hadoop/py311env/lib/python3.11/site-packages (from transformers) (0.21.1)
Requirement already satisfied: safetensors>=0.4.3 in
/home/hadoop/py311env/lib/python3.11/site-packages (from transformers) (0.5.3)
Requirement already satisfied: hf-xet<2.0.0,>=1.1.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from huggingface-
hub<1.0,>=0.30.0->transformers) (1.1.2)
Requirement already satisfied: py4j==0.10.9.9 in
/home/hadoop/py311env/lib/python3.11/site-packages (from pyspark) (0.10.9.9)
Requirement already satisfied: scipy>=1.6.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from scikit-learn) (1.15.3)
Requirement already satisfied: threadpoolctl>=3.1.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from scikit-learn) (3.6.0)
Requirement already satisfied: geographiclib<3,>=1.52 in
/home/hadoop/py311env/lib/python3.11/site-packages (from geopy) (2.0)
Requirement already satisfied: wheel<1.0,>=0.23.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
astunparse>=1.6.0->tensorflow==2.15.0) (0.45.1)
Requirement already satisfied: marisa-trie>=1.1.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from language-
data>=1.2->langcodes<4.0.0,>=3.2.0->spacy) (1.2.1)
Requirement already satisfied: oauthlib>=3.0.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from requests-
oauthlib>=0.7.0->google-auth-
oauthlib<2,>=0.5->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (3.3.1)
Requirement already satisfied: markdown-it-py>=2.2.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
rich>=10.11.0->typer<1.0.0,>=0.3.0->spacy) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
rich>=10.11.0->typer<1.0.0,>=0.3.0->spacy) (2.19.1)
Requirement already satisfied: mdurl~=0.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from markdown-it-
py>=2.2.0->rich>=10.11.0->typer<1.0.0,>=0.3.0->spacy) (0.1.2)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from sympy>=1.13.3->torch)
(1.3.0)
Requirement already satisfied: MarkupSafe>=2.1.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
werkzeug>=1.0.1->tensorboard<2.16,>=2.15->tensorflow==2.15.0) (3.0.2)
Note: you may need to restart the kernel to use updated packages.

```
[3]: %pip install seqeval torchcrf
```

Requirement already satisfied: seqeval in
/home/hadoop/py311env/lib/python3.11/site-packages (1.2.2)
Requirement already satisfied: torchcrf in
/home/hadoop/py311env/lib/python3.11/site-packages (1.1.0)
Requirement already satisfied: numpy>=1.14.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from seqeval) (1.26.4)
Requirement already satisfied: scikit-learn>=0.21.3 in
/home/hadoop/py311env/lib/python3.11/site-packages (from seqeval) (1.6.1)
Requirement already satisfied: torch>=1.0.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torchcrf) (2.7.0)
Requirement already satisfied: scipy>=1.6.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from scikit-
learn>=0.21.3->seqeval) (1.15.3)
Requirement already satisfied: joblib>=1.2.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from scikit-
learn>=0.21.3->seqeval) (1.5.1)
Requirement already satisfied: threadpoolctl>=3.1.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from scikit-
learn>=0.21.3->seqeval) (3.6.0)
Requirement already satisfied: filelock in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(3.18.0)
Requirement already satisfied: typing-extensions>=4.10.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(4.13.2)
Requirement already satisfied: sympy>=1.13.3 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(1.14.0)
Requirement already satisfied: networkx in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(3.5)
Requirement already satisfied: jinja2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(3.1.6)
Requirement already satisfied: fsspec in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(2025.3.0)
Requirement already satisfied: nvidia-cuda-nvrtc-cu12==12.6.77 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(12.6.77)
Requirement already satisfied: nvidia-cuda-runtime-cu12==12.6.77 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(12.6.77)
Requirement already satisfied: nvidia-cuda-cupti-cu12==12.6.80 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)

(12.6.80)
Requirement already satisfied: nvidia-cudnn-cu12==9.5.1.17 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(9.5.1.17)
Requirement already satisfied: nvidia-cublas-cu12==12.6.4.1 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(12.6.4.1)
Requirement already satisfied: nvidia-cufft-cu12==11.3.0.4 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(11.3.0.4)
Requirement already satisfied: nvidia-curand-cu12==10.3.7.77 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(10.3.7.77)
Requirement already satisfied: nvidia-cusolver-cu12==11.7.1.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(11.7.1.2)
Requirement already satisfied: nvidia-cusparse-cu12==12.5.4.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(12.5.4.2)
Requirement already satisfied: nvidia-cusparselt-cu12==0.6.3 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(0.6.3)
Requirement already satisfied: nvidia-nccl-cu12==2.26.2 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(2.26.2)
Requirement already satisfied: nvidia-nvtx-cu12==12.6.77 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(12.6.77)
Requirement already satisfied: nvidia-nvjitlink-cu12==12.6.85 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(12.6.85)
Requirement already satisfied: nvidia-cufile-cu12==1.11.1.6 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(1.11.1.6)
Requirement already satisfied: triton==3.3.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from torch>=1.0.0->torchcrf)
(3.3.0)
Requirement already satisfied: setuptools>=40.8.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
triton==3.3.0->torch>=1.0.0->torchcrf) (65.5.0)
Requirement already satisfied: mpmath<1.4,>=1.1.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
sympy>=1.13.3->torch>=1.0.0->torchcrf) (1.3.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/home/hadoop/py311env/lib/python3.11/site-packages (from
jinja2->torch>=1.0.0->torchcrf) (3.0.2)
Note: you may need to restart the kernel to use updated packages.

```
[4]: !jupyter nbextension enable --py widgetsnbextension
```

```
usage: jupyter [-h] [--version] [--config-dir] [--data-dir] [--runtime-dir]
               [--paths] [--json] [--debug]
               [subcommand]

Jupyter: Interactive Computing

positional arguments:
  subcommand     the subcommand to launch

options:
  -h, --help     show this help message and exit
  --version      show the versions of core jupyter packages and exit
  --config-dir   show Jupyter config dir
  --data-dir     show Jupyter data dir
  --runtime-dir  show Jupyter runtime dir
  --paths        show all Jupyter paths. Add --json for machine-readable
                 format.
  --json         output paths as machine-readable json
  --debug        output debug information about paths

Available subcommands: console dejavu events execute kernel kernelspec lab
labextension labhub migrate nbconvert notebook run server troubleshoot trust

Jupyter command `jupyter-nbextension` not found.
```

```python
[5]: import os
     os.environ["JAVA_HOME"] = "/usr/lib/jvm/java-11-openjdk-amd64"
     os.environ["SPARK_HOME"] = "/opt/spark/spark-3.5.6-bin-hadoop3"
     os.environ["HADOOP_HOME"] = "/usr/local/hadoop"
     os.environ["TF_USE_LEGACY_KERAS"] = "1"
```

```python
[6]: import findspark
     findspark.init()
     import pyspark
```

```python
[7]: #Import necessary libraries
     import pandas as pd    # Pandas is an open source, BSD-licensed library␣
      ↪providing high-performance, easy-to-use data structures and data analysis␣
      ↪tools for the Python programming language. Pandas Series is a␣
      ↪one-dimensional labeled array capable of holding any data type with axis␣
      ↪labels or index
     import geopandas as gpd
     import time
     import matplotlib.pyplot as plt
     import numpy as np
```

```python
import logging
import hashlib
from geopy.geocoders import Nominatim
from geopy.extra.rate_limiter import RateLimiter
from pyspark.sql import functions as func
from pyspark.sql.types import IntegerType, StringType, FloatType,
 ↪TimestampType, BinaryType
from pyspark.sql.functions import col, count, when, mean, stddev, abs, sum,
 ↪row_number
from pyspark.ml.feature import VectorAssembler, StandardScaler, StringIndexer,
 ↪OneHotEncoder
from pyspark.ml import Pipeline
from pyspark.ml.classification import RandomForestClassifier
from pyspark.ml.tuning import CrossValidator, ParamGridBuilder
from pyspark.ml.evaluation import MulticlassClassificationEvaluator,
 ↪BinaryClassificationEvaluator
from sklearn.metrics import precision_recall_curve
from pyspark.sql import Window
from transformers import pipeline, AutoTokenizer,
 ↪AutoModelForSequenceClassification
from shapely.geometry import Point
from tqdm import tqdm
import torch
import re
```

2025-07-11 18:19:17.648111: E
external/local_xla/xla/stream_executor/cuda/cuda_dnn.cc:9261] Unable to register
cuDNN factory: Attempting to register factory for plugin cuDNN when one has
already been registered
2025-07-11 18:19:17.648179: E
external/local_xla/xla/stream_executor/cuda/cuda_fft.cc:607] Unable to register
cuFFT factory: Attempting to register factory for plugin cuFFT when one has
already been registered
2025-07-11 18:19:17.650399: E
external/local_xla/xla/stream_executor/cuda/cuda_blas.cc:1515] Unable to
register cuBLAS factory: Attempting to register factory for plugin cuBLAS when
one has already been registered
2025-07-11 18:19:17.663466: I tensorflow/core/platform/cpu_feature_guard.cc:182]
This TensorFlow binary is optimized to use available CPU instructions in
performance-critical operations.
To enable the following instructions: AVX2 FMA, in other operations, rebuild
TensorFlow with the appropriate compiler flags.
2025-07-11 18:19:18.709380: W
tensorflow/compiler/tf2tensorrt/utils/py_utils.cc:38] TF-TRT Warning: Could not
find TensorRT

```
[8]:  # Start SparkSession
      from pyspark.sql import SparkSession
      spark=SparkSession.builder.appName("Sudan Crisis Analysis").config("spark.
       ↪driver.memory", "4g").getOrCreate()
      spark
```

```
25/07/11 18:19:22 WARN Utils: Your hostname, julius-virtual-machine resolves to
a loopback address: 127.0.1.1; using 192.168.145.130 instead (on interface
ens33)
25/07/11 18:19:22 WARN Utils: Set SPARK_LOCAL_IP if you need to bind to another
address
Setting default log level to "WARN".
To adjust logging level use sc.setLogLevel(newLevel). For SparkR, use
setLogLevel(newLevel).
25/07/11 18:19:23 WARN NativeCodeLoader: Unable to load native-hadoop library
for your platform… using builtin-java classes where applicable
25/07/11 18:19:24 WARN Utils: Service 'SparkUI' could not bind on port 4040.
Attempting port 4041.
```

[8]: <pyspark.sql.session.SparkSession at 0x7f64dae560d0>

```
[9]:  # Load CSV data from Event Detection Step
      df = pd.read_csv('event_topic_results.csv')
```

```
[10]: # Identify Text Column
      print("Columns in DataFrame:", df.columns)
      text_col = None
      for col in ['text', 'Text', 'tweet', 'Tweet', 'content', 'Clean_Text']:
          if col in df.columns:
              text_col = col
              break
      if text_col is None:
          raise ValueError("No text column found! Please check your CSV and set the␣
       ↪correct column name.")
```

```
Columns in DataFrame: Index(['_id', 'userId', 'userName', 'alias',
'profilePicture', 'userCreatedAt',
        'bio', 'followers', 'following', 'lists', 'statusesCount', 'verified',
        'userLocation', 'lang', 'type', 'text', 'createdAt', 'mentions',
        'totalRetweets', 'favorites', 'replies', 'links', 'firstLink', 'images',
        'impressions', 'isImage', 'firstImage', 'location', 'url',
        'noteTweetText', 'inReplyTo', 'inReplyToId', 'inReplyToUserId',
        'reportName', 'Latitude', 'Longitude', 'displacement', 'armed conflict',
        'protest suppression', 'sexual violence', 'famine',
        'infrastructure destruction', 'looting', 'Predicted_Events', 'Topic',
        'Topic_Probability'],
      dtype='object')
```

```python
[11]: # Clean Tweets
      def clean_tweet(text):
          text = re.sub(r"http\S+|www\S+|https\S+", '', str(text), flags=re.
        ↪MULTILINE)  # Remove URLs
          text = re.sub(r'@\w+', '', text)  # Remove mentions
          text = re.sub(r'#', '', text)  # Remove hashtag symbol only
          text = text.strip()
          return text

      df['Clean_Text'] = df[text_col].apply(clean_tweet)
```

```python
[12]: # Named Entity Recognition (NER)
      from transformers import AutoTokenizer, AutoModelForTokenClassification
      import torch

      tokenizer = AutoTokenizer.from_pretrained("dslim/bert-base-NER")
      model = AutoModelForTokenClassification.from_pretrained("dslim/bert-base-NER")
      model.eval()

      def extract_entities(text):
          tokens = tokenizer(text, return_tensors="pt", truncation=True,␣
        ↪max_length=128)
          with torch.no_grad():
              outputs = model(**tokens)
          predictions = torch.argmax(outputs.logits, dim=2)
          tokens_list = tokenizer.convert_ids_to_tokens(tokens["input_ids"][0])
          entities = []
          current_entity = []
          current_label = None
          for token, label_idx in zip(tokens_list, predictions[0].tolist()):
              label = model.config.id2label[label_idx]
              if label.startswith("B-"):
                  if current_entity:
                      entities.append((" ".join(current_entity), current_label))
                      current_entity = []
                  current_entity.append(token.replace("##", ""))
                  current_label = label[2:]
              elif label.startswith("I-") and current_label == label[2:]:
                  current_entity.append(token.replace("##", ""))
              else:
                  if current_entity:
                      entities.append((" ".join(current_entity), current_label))
                      current_entity = []
                      current_label = None
          if current_entity:
              entities.append((" ".join(current_entity), current_label))
          return entities
```

```
df['Entities'] = df['Clean_Text'].apply(extract_entities)
```
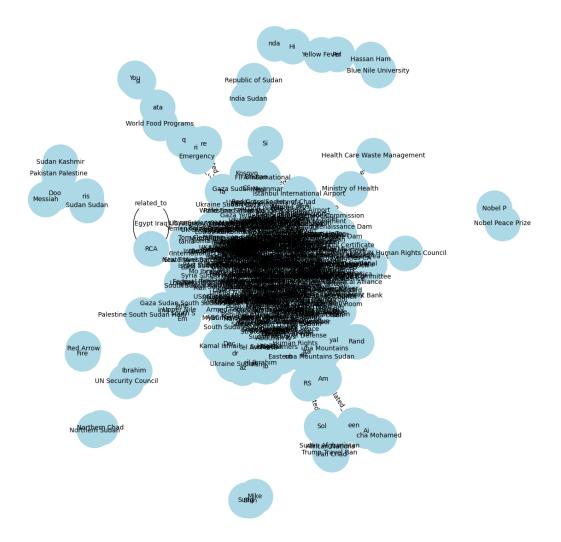
tokenizer_config.json: 0%| | 0.00/59.0 [00:00<?, ?B/s]

config.json: 0%| | 0.00/829 [00:00<?, ?B/s]

vocab.txt: 0.00B [00:00, ?B/s]

added_tokens.json: 0%| | 0.00/2.00 [00:00<?, ?B/s]

special_tokens_map.json: 0%| | 0.00/112 [00:00<?, ?B/s]

model.safetensors: 0%| | 0.00/433M [00:00<?, ?B/s]

Some weights of the model checkpoint at dslim/bert-base-NER were not used when
initializing BertForTokenClassification: ['bert.pooler.dense.bias',
'bert.pooler.dense.weight']
- This IS expected if you are initializing BertForTokenClassification from the
checkpoint of a model trained on another task or with another architecture (e.g.
initializing a BertForSequenceClassification model from a BertForPreTraining
model).
- This IS NOT expected if you are initializing BertForTokenClassification from
the checkpoint of a model that you expect to be exactly identical (initializing
a BertForSequenceClassification model from a BertForSequenceClassification
model).

[13]:
```python
# Relation Extraction (Simple Heuristic)
import spacy
nlp = spacy.load("en_core_web_sm")

def extract_relations(text, entities):
    doc = nlp(text)
    relations = []
    # Simple heuristic: consider pairs of entities in the same sentence with␣
 ↪verbs linking them
    for sent in doc.sents:
        sent_text = sent.text
        sent_entities = [ent for ent in entities if ent[0] in sent_text]
        if len(sent_entities) < 2:
            continue
        # For each pair, check for verbs connecting them
        for i in range(len(sent_entities)):
            for j in range(i+1, len(sent_entities)):
                ent1 = sent_entities[i][0]
                ent2 = sent_entities[j][0]
                if any(tok.pos_ == "VERB" for tok in sent):
                    relations.append((ent1, "related_to", ent2))
    return relations
```

```python
df['Relations'] = df.apply(lambda row: extract_relations(row['Clean_Text'],
  ↪row['Entities']), axis=1)
```

```python
[14]: # Build and Visualize Entity-Relation Graph
import networkx as nx
import matplotlib.pyplot as plt

G = nx.Graph()
for relations in df['Relations']:
    for ent1, rel, ent2 in relations:
        G.add_node(ent1)
        G.add_node(ent2)
        G.add_edge(ent1, ent2, label=rel)

plt.figure(figsize=(12, 12))
pos = nx.spring_layout(G, k=0.5)
nx.draw(G, pos, with_labels=True, node_size=3000, node_color='lightblue',
  ↪font_size=10)
edge_labels = nx.get_edge_attributes(G, 'label')
nx.draw_networkx_edge_labels(G, pos, edge_labels=edge_labels)
plt.title("Entity-Relation Graph from Sudan Crisis Tweets")
plt.show()
```

Entity-Relation Graph from Sudan Crisis Tweets

```
[15]:  # Save Results
       df.to_csv("ner_relation_results.csv", index=False)
       print("Saved NER and relation extraction results to ner_relation_results.csv")
```

Saved NER and relation extraction results to ner_relation_results.csv

```
[ ]:
```