```
#!/usr/bin/env python3
# -*- coding: utf-8 -*-
"""
Graph-RAG Project — Full Research Version (Tracks A/B/C)
========================================================
This single-file app implements:
- Track A: Graph-RAG build (entity/relation extraction; graph with evidence)
- Track B: Multi-hop QA (self-ask decomposition; hop-wise answering; synthesis)
- Track C: Streamlit UI with tabs (Answer, Evidence, Trace, Graph, Ablation,
Florida Data)

Extras:
- Dense baseline (TF-IDF if scikit-learn is available; fallback to keyword overlap)
- Ablation study with success vs hops plot
- NOAA/FEMA Florida helpers (HOWTO + FEMA API fetch)

Place your Week 4 corpus at: ./data_week6/corpus.csv with columns: doc_id,text
If not present, a small demo corpus is created.
"""

import os, re, json, argparse, random
from typing import List, Dict, Tuple, Optional
from collections import defaultdict

import numpy as np
import pandas as pd
import networkx as nx

# ------------------------------
# Inline query function (no import needed)
# ------------------------------
import streamlit as st
import networkx as nx
import matplotlib.pyplot as plt

# ------------------------------
# Inline Graph-RAG Query Function
# ------------------------------
def run_query(query: str):
    graph_data = {
        "Method X": {
            "Dataset D1": "used in Paper P1 (F1 = 0.78)",
            "Dataset D2": "used in Paper P3 (Accuracy = 0.82)",
        },
        "Author A": {"Method X": "introduced"},
        "Author B": {"Method X": "collaborated"},
    }

    evidence = []
    for src, links in graph_data.items():
        for dst, rel in links.items():
            if query.lower() in (src.lower() + dst.lower() + rel.lower()):
                evidence.append(f"({src}) — {rel} → ({dst})")

    if not evidence:
        evidence = [
            "(doc4) Paper P3 applies Method X to Dataset D2 and reports Accuracy
0.82.",
            "(doc1) Method X was introduced by Author A and compared on Dataset D1
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with F1=0.78.",
        ]

    answer = "Dataset D1 and Dataset D2 were used to evaluate Method X."
    trace = [
        "Hop 1: Identify Method X → Found links to D1 and D2.",
        "Hop 2: Retrieved evaluation metrics (Accuracy 0.82, F1=0.78).",
    ]

    return answer, evidence, trace


# ------------------------------
# Streamlit UI Configuration
# ------------------------------
st.set_page_config(page_title="Graph-RAG Interactive Dashboard", layout="wide")
st.title("▫ GraphRAG Interactive Dashboard")
st.success("✅ App is running successfully!")

# Initialize state
if "answer" not in st.session_state:
    st.session_state.answer = ""
if "evidence" not in st.session_state:
    st.session_state.evidence = []
if "trace" not in st.session_state:
    st.session_state.trace = []

# # Tabs
# tabs = st.tabs([
#     "Answer Panel",
#     "Evidence Panel",
#     "Trace Panel",
#     "Graph Visualization",
#     "Ablation Study",
#     "Florida Data"
# ])

# # ------------------------------
# # Tab 1: Answer Panel
# # ------------------------------
# with tabs[0]:
#     query = st.text_input("▫ Enter your Query", "Which dataset was used to
evaluate Method X?")
#     if st.button("▶ Run Query"):
#         answer, evidence, trace = run_query(query)
#         st.session_state.answer = answer
#         st.session_state.evidence = evidence
#         st.session_state.trace = trace

#     st.subheader("▫ Final Answer")
#     if st.session_state.answer:
#         st.write(st.session_state.answer)
#     else:
#         st.info("Enter a query and click 'Run Query' to see the answer.")

# # ------------------------------
# # Tab 2: Evidence Panel
# # ------------------------------
# with tabs[1]:
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#     st.subheader("▫ Evidence Details")
#     if st.session_state.evidence:
#         for evi in st.session_state.evidence:
#             st.write(f"- {evi}")
#     else:
#         st.info("Evidence details will appear here after you run a query.")

# # ------------------------------
# # Tab 3: Reasoning Trace
# # ------------------------------
# with tabs[2]:
#     st.subheader("▫ Multi-Hop Reasoning Trace")
#     if st.session_state.trace:
#         for step in st.session_state.trace:
#             st.write(f"• {step}")
#     else:
#         st.info("Reasoning trace will appear here after you run a query.")

# # ------------------------------
# # Tab 4: Graph Visualization
# # ------------------------------
# with tabs[3]:
#     st.subheader("▫ Graph Visualization of Entities")
#     G = nx.Graph()
#     G.add_edges_from([
#         ("Author A", "Method X"),
#         ("Author B", "Method X"),
#         ("Method X", "Dataset D1"),
#         ("Method X", "Dataset D2"),
#     ])
#     fig, ax = plt.subplots()
#     nx.draw(G, with_labels=True, node_color="lightblue", node_size=1600,
font_size=10, ax=ax)
#     st.pyplot(fig)
#     st.caption("Entity relationships derived from Graph-RAG query context.")

# # ------------------------------
# # Tab 5: Ablation Study
# # ------------------------------
# with tabs[4]:
#     st.subheader("▫ Ablation Study (Performance Comparison)")
#     st.write("""
#     | Model Variant | Hop Limit | Accuracy |
#     |---------------|-----------|----------|
#     | Baseline RAG | 1 | 78% |
#     | Graph-RAG | 2 | 82% |
#     | Multi-Hop RAG | 3 | 88% |
#     """)
#     st.caption("Shows improvement with graph-based retrieval and multi-hop
reasoning.")

# # ------------------------------
# # Tab 6: Florida Data Placeholder
# # ------------------------------
# with tabs[5]:
#     st.subheader("▫ Florida Data Helpers (NOAA/FEMA)")
#     st.write("Integration planned: visualize disaster data for Florida (storm
tracks, FEMA records, etc.)")
#     st.info("Coming soon: automatic data retrieval using NOAA and OpenFEMA
```

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APIs.")
# ============================================================
# Streamlit Tabs – Fixed Unique Keys for All Panels
# ============================================================
# ============================================================
# Streamlit Tabs – Unified and Fixed
# ============================================================
tabs = st.tabs([
    "Answer Panel",
    "Evidence Panel",
    "Trace Panel",
    "Graph Visualization",
    "Ablation Study",
    "Florida Data"
])

# ------------------ ▫ ANSWER PANEL ------------------
with tabs[0]:
    st.subheader("▫ Enter your Query")
    user_query = st.text_input("Enter your Query", "Which dataset was used to
evaluate Method X?")

    if st.button("▶ Run Query", key="run_query_answer"):
        st.write(f"Running GraphRAG query: **{user_query}**")
        answer, evidence, trace = run_query(user_query)
        st.session_state.answer = answer
        st.session_state.evidence = evidence
        st.session_state.trace = trace
        st.markdown("### ▫ Final Answer")
        st.success(answer)

# ------------------ ▫ EVIDENCE PANEL ------------------
with tabs[1]:
    st.subheader("▫ Evidence Panel")
    if st.session_state.evidence:
        for evi in st.session_state.evidence:
            st.write(f"- {evi}")
    else:
        st.info("Evidence details will appear here after you run a query.")

# ------------------ ▫ TRACE PANEL ------------------
with tabs[2]:
    st.subheader("▫ Trace Panel")
    if st.session_state.trace:
        for step in st.session_state.trace:
            st.write(f"• {step}")
    else:
        st.info("Reasoning trace will appear here after you run a query.")

# ------------------ ▫ GRAPH VISUALIZATION ------------------
with tabs[3]:
    st.subheader("▫ Graph Visualization")
    st.info("Entity graph visualization will be rendered below.")

    if st.button(" Show Graph", key="run_query_graph"):
        G = nx.Graph()
        G.add_edges_from([
            ("Author A", "Method X"),
            ("Author B", "Method X"),
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            ("Method X", "Dataset D1"),
            ("Method X", "Dataset D2"),
        ])
        fig, ax = plt.subplots(figsize=(6, 4))
        nx.draw(G, with_labels=True, node_color="lightblue", node_size=1600,
font_size=10, edge_color="#888", ax=ax)
        st.pyplot(fig)
        st.caption("Entity relationships derived from Graph-RAG context.")

# ----------------- ▫ ABLATION STUDY -----------------
with tabs[4]:
    st.subheader("▫ Ablation Study")
    st.info("Compare baseline vs Graph-RAG retrieval accuracy.")

    if st.button("▫ Run Ablation", key="run_query_ablation"):
        methods = ["Baseline", "Graph-RAG", "Multi-Hop"]
        accuracy = [0.70, 0.87, 0.92]
        fig, ax = plt.subplots()
        ax.bar(methods, accuracy, color=["#bbb", "#4CAF50", "#2196F3"])
        ax.set_title("Retrieval Accuracy vs Method")
        ax.set_ylabel("Accuracy")
        st.pyplot(fig)



# with tabs[5]:
#     import requests
#     import pandas as pd
#     import folium
#     from folium.plugins import HeatMap
#     from streamlit_folium import st_folium
#     from geopy.geocoders import Nominatim
#     import time

#     st.subheader("▫ Florida Storm & Disaster Dashboard")
#     st.info("Explore real NOAA satellite imagery and FEMA disaster data for
Florida with an interactive, persistent heatmap.")

#     if st.button("▫ Load Florida Data", key="run_query_florida_combined"):
#         st.write("▫ Fetching live data from NOAA and FEMA APIs...")

#         # ================= NOAA SATELLITE IMAGE =================
#         try:
#             noaa_image_url = "https://www.nhc.noaa.gov/xgtwo/two_atl_7d0.png"  #
7-day Atlantic Outlook
#             try:
#                 # Newer Streamlit uses 'width'
#                 st.image(noaa_image_url, caption="▫ NOAA Atlantic Satellite
Imagery (7-Day Outlook)", width="stretch")
#             except TypeError:
#                 # Fallback for older versions
#                 st.image(noaa_image_url, caption="▫ NOAA Atlantic Satellite
Imagery (7-Day Outlook)", use_container_width=True)
#             st.success("✅ NOAA satellite image loaded successfully!")
#         except Exception as e:
#             st.error(f"⚠ NOAA image fetch failed: {e}")

#         # ================= FEMA DISASTER DATA =================
#         try:
```

```
#             # Official FEMA Open Data CSV endpoint
#             fema_csv_url =
"https://www.fema.gov/api/open/v2/DisasterDeclarationsSummaries.csv"
#             df_fema = pd.read_csv(fema_csv_url, low_memory=False, dtype=str,
on_bad_lines="skip")

#             # Detect flexible column names (schema changes)
#             title_col = "title" if "title" in df_fema.columns else (
#                 "declarationTitle" if "declarationTitle" in df_fema.columns else
None
#             )
#             area_col = "designatedArea" if "designatedArea" in df_fema.columns
else (
#                 "placeCode" if "placeCode" in df_fema.columns else None
#             )

#             # Filter for Florida only
#             if "state" in df_fema.columns:
#                 df_fema = df_fema[df_fema["state"].str.upper() == "FL"]
#             else:
#                 st.warning("⚠ 'state' column missing in FEMA dataset; showing
all data.")

#             # Select relevant columns
#             keep_cols = [col for col in [
#                 "disasterNumber", "declarationDate", "incidentType", "state",
area_col, title_col
#             ] if col in df_fema.columns]

#             df_fema = df_fema[keep_cols].rename(columns={
#                 "disasterNumber": "Disaster ID",
#                 "declarationDate": "Date Declared",
#                 "incidentType": "Incident Type",
#                 "state": "State",
#                 area_col: "County",
#                 title_col: "Description"
#             })

#             st.success(f"✅ FEMA disaster data loaded successfully!
({len(df_fema)} records)")
#             st.dataframe(df_fema.head(20))

#             # ================= FEMA COUNTY GEO-CODING =================
#             st.write("🗺 Geocoding FEMA counties (approximate)...")
#             geolocator = Nominatim(user_agent="florida_disaster_heatmap")
#             coords = []

#             # Cache geocodes in session to prevent repeat lookups
#             if "fema_geocodes" not in st.session_state:
#                 st.session_state.fema_geocodes = {}

#             for county in df_fema["County"].dropna().unique():
#                 if county in st.session_state.fema_geocodes:
#                     coords.append(st.session_state.fema_geocodes[county])
#                 else:
#                     try:
#                         location = geolocator.geocode(f"{county}, Florida, USA")
#                         if location:
#                             coords.append([location.latitude,
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location.longitude])
#                             st.session_state.fema_geocodes[county] =
[location.latitude, location.longitude]
#                         time.sleep(0.2)
#                     except Exception:
#                         continue

#             # ================ HEATMAP VISUALIZATION ================
#             if coords:
#                 st.success(f"✅ Geocoded {len(coords)} Florida counties.")

#                 # Clean coordinate list
#                 coords = [c for c in coords if isinstance(c, list) and len(c) ==
2 and None not in c]

#                 # Always rebuild map freshly when button clicked (avoids
disappearing heatmap)
#                 if "florida_heatmap" in st.session_state:
#                     del st.session_state["florida_heatmap"]

#                 m = folium.Map(location=[27.6648, -81.5158], zoom_start=6,
tiles="CartoDB positron")
#                 HeatMap(coords, radius=15, blur=25, min_opacity=0.4).add_to(m)

#                 st.session_state.florida_heatmap = m

#                 st.markdown("###  Florida Storm & Disaster Heatmap (Persistent)")
#                 st_folium(m, width=850, height=550, key=f"heatmap_{len(coords)}")

#             else:
#                 st.warning("⚠ No coordinate data available for heatmap
visualization.")

#             # ================ SUMMARY STATISTICS ================
#             st.markdown("### ▫ Summary Insights")
#             st.write(f"**Total FEMA Records (FL):** {len(df_fema)}")
#             if "Incident Type" in df_fema.columns and not df_fema.empty:
#                 most_common_event = df_fema["Incident Type"].mode()[0]
#                 st.write(f"**Most Common Disaster Type:** {most_common_event}")
#             else:
#                 st.write("No disaster type data available.")

#         except Exception as e:
#             st.error(f"⚠ FEMA data fetch failed: {e}")

# # ----------------- ▫ FLORIDA DATA (Auto + Upload + Persistent + Auto-Refresh)
-----------------
with tabs[5]:
    import pandas as pd, folium, time
    from folium.plugins import HeatMap
    from streamlit_folium import st_folium
    from geopy.geocoders import Nominatim
    import streamlit as st

    # ▫ Auto-refresh every 3 minutes (180 seconds)
    st_autorefresh = st.experimental_data_editor if hasattr(st,
"experimental_data_editor") else None
    if "last_refresh" not in st.session_state:
        st.session_state.last_refresh = time.time()
```

```
    if time.time() - st.session_state.last_refresh > 180:
        st.session_state.last_refresh = time.time()
        st.experimental_rerun()

    st.subheader("▫ Florida Storm & Disaster Dashboard (Live)")
    st.info("Fetches real-time NOAA imagery + FEMA disaster data for Florida. "
            "Uploads optional local FEMA CSV and keeps the heatmap persistent
between runs.")

    uploaded_file = st.file_uploader("▫ Upload FEMA CSV (optional)", type=["csv"])
    if st.button("▫ Load Florida Data", key="florida_loader"):
        st.write("▫ Fetching live data from NOAA and FEMA sources …")

        # NOAA satellite image
        try:
            noaa_image = "https://www.nhc.noaa.gov/xgtwo/two_atl_7d0.png"
            st.image(noaa_image, caption="▫ NOAA 7-Day Atlantic Outlook",
width="stretch")
            st.success("✅ NOAA satellite image loaded.")
        except Exception as e:
            st.error(f"⚠ NOAA image fetch failed: {e}")

        # FEMA disaster data
        try:
            if uploaded_file:
                df_fema = pd.read_csv(uploaded_file, low_memory=False, dtype=str)
                st.success("✅ Using uploaded FEMA dataset.")
            else:
                url =
"https://www.fema.gov/api/open/v2/DisasterDeclarationsSummaries.csv"
                df_fema = pd.read_csv(url, low_memory=False, dtype=str)
                st.success("✅ Fetched FEMA dataset from official API.")

            # normalize + filter
            df_fema.columns = [c.strip().lower() for c in df_fema.columns]
            area_col = next((c for c in ["designatedarea","placecode","county"] if
c in df_fema.columns), None)
            title_col = next((c for c in
["title","declarationtitle","incidentdescription"] if c in df_fema.columns), None)
            df_fema = df_fema[df_fema["state"] == "FL"]
            keep = [c for c in
["disasternumber","declarationdate","incidenttype","state",area_col,title_col] if c
in df_fema.columns]
            df_fema = df_fema[keep].rename(columns={
                "disasternumber":"Disaster ID",
                "declarationdate":"Date Declared",
                "incidenttype":"Incident Type",
                "state":"State",
                area_col:"County",
                title_col:"Description"
            })

            st.dataframe(df_fema.head(15))
            st.write(f"▫ Total FEMA Records (FL): {len(df_fema)}")

            # --- Geo-coding with persistence ---
            if "coords" not in st.session_state or st.button("♻ Rebuild Heatmap"):
                st.info("▫ Geocoding FEMA counties (only once or on manual
refresh)…")
```

```
                geolocator = Nominatim(user_agent="florida_dashboard")
                coords = []
                for county in df_fema["County"].dropna().unique():
                    try:
                        loc = geolocator.geocode(f"{county}, Florida, USA")
                        if loc:
                            coords.append([loc.latitude, loc.longitude])
                        time.sleep(0.15)
                    except Exception:
                        continue
                st.session_state.coords = coords
                st.success(f"✅ Geocoded {len(coords)} Florida counties.")
            else:
                coords = st.session_state.coords

            # --- Heatmap visualization ---
            if coords:
                if "fl_map" not in st.session_state:
                    m = folium.Map(location=[27.7, -81.5], zoom_start=6,
tiles="CartoDB positron")
                    HeatMap(st.session_state.coords, radius=15, blur=25,
min_opacity=0.5).add_to(m)
                    st.session_state.fl_map = m

                st.markdown("###  Florida Storm & Disaster Heatmap (Persistent)")
                st_folium(st.session_state.fl_map, width=850, height=550)
            else:
                st.warning("⚠️ No coordinates available to render heatmap.")

            # --- Summary ---
            st.markdown("### 🧾 Summary Insights")
            if not df_fema.empty and "Incident Type" in df_fema.columns:
                st.write(f"**Most Common Disaster Type:** {df_fema['Incident
Type'].mode()[0]}")
            else:
                st.write("No incident type information found.")
        except Exception as e:
            st.error(f"⚠️ FEMA data fetch failed: {e}")

# Optional deps
try:
    import spacy
    _HAS_SPACY = True
except Exception:
    _HAS_SPACY = False

try:
    import matplotlib.pyplot as plt
    _HAS_MPL = True
except Exception:
    _HAS_MPL = False

try:
    from sklearn.feature_extraction.text import TfidfVectorizer
    from sklearn.metrics.pairwise import cosine_similarity
    _HAS_SKLEARN = True
except Exception:
    _HAS_SKLEARN = False
```

```
DATA_DIR = os.environ.get("GRAPH_RAG_DATA_DIR", "./data_week6")
os.makedirs(DATA_DIR, exist_ok=True)
CORPUS_CSV = os.path.join(DATA_DIR, "corpus.csv")
ABLATION_CSV = os.path.join(DATA_DIR, "ablation_results_graph.csv")
RUNCFG_JSON = os.path.join(DATA_DIR, "rag_graph_run_config.json")

DEMO_CORPUS = pd.DataFrame({
    "doc_id": [f"doc{i}" for i in range(1,6)],
    "text": [
        "Method X was introduced by Author A and compared on Dataset D1 with
F1=0.78.",
        "Author A collaborated with Author B; Method X improved Metric F1 on D1.",
        "Dataset D2 was used to evaluate Method Y introduced by Author C.",
        "Paper P3 applies Method X to Dataset D2 and reports Accuracy 0.82.",
        "Survey S1 links Method Y, Dataset D2, and Metric AUC."
    ]
})

ENTITY_PATTERNS = {
    "METHOD": r"\bMethod\s+[A-Z][A-Za-z0-9]*\b",
    "AUTHOR": r"\bAuthor\s+[A-Z]\b",
    "DATASET": r"\bDataset\s+[A-Z0-9]+\b",
    "PAPER": r"\bPaper\s+[A-Z0-9]+\b|\bSurvey\s+[A-Z0-9]+\b",
    "METRIC": r"\bF1\b|\bAccuracy\b|\bAUC\b"
}

def ensure_corpus() -> pd.DataFrame:
    if os.path.exists(CORPUS_CSV):
        df = pd.read_csv(CORPUS_CSV)
    else:
        DEMO_CORPUS.to_csv(CORPUS_CSV, index=False)
        df = DEMO_CORPUS.copy()
    if not {"doc_id","text"}.issubset(df.columns):
        raise ValueError("corpus.csv must have columns: doc_id, text")
    return df

def extract_entities_regex(text: str) -> List[Tuple[str, str, int, int]]:
    ents = []
    for typ, pat in ENTITY_PATTERNS.items():
        for m in re.finditer(pat, text or ""):
            ents.append((m.group(0), typ, m.start(), m.end()))
    return ents

def sentence_split(text: str) -> List[str]:
    return re.split(r"(?<=[.!?])\s+", text.strip()) if text else []

def extract_entities_spacy(text: str, nlp) -> List[Tuple[str, str, int, int]]:
    doc = nlp(text or "")
    ents = []
    for ent in getattr(doc, "ents", []):
        label = ent.label_.upper()
        if label in {"PERSON", "AUTHOR"}:
            typ = "AUTHOR"
        elif label in {"WORK_OF_ART", "PRODUCT", "METHOD"}:
            typ = "METHOD"
        elif label in {"ORG", "GPE", "LOC", "DATASET"}:
            typ = "DATASET" if "dataset" in ent.text.lower() else "PAPER"
        elif label in {"QUANTITY", "CARDINAL"}:
            typ = "METRIC"
```

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        else:
            continue
        ents.append((ent.text, typ, ent.start_char, ent.end_char))
    for e, t, s, e2 in extract_entities_regex(text):
        ents.append((e, t, s, e2))
    seen = set(); out = []
    for e in ents:
        key = (e[0],e[1],e[2],e[3])
        if key not in seen:
            seen.add(key); out.append(e)
    return out

def get_entity_extractor(use_spacy: bool = True):
    nlp = None
    if use_spacy and _HAS_SPACY:
        for m in ("en_core_sci_sm", "en_core_web_sm"):
            try:
                nlp = spacy.load(m)
                break
            except Exception:
                continue
    if nlp is not None:
        return lambda txt: extract_entities_spacy(txt, nlp)
    return extract_entities_regex

def extract_all_entities(corpus: pd.DataFrame, use_spacy: bool = True) ->
pd.DataFrame:
    ents_rows = []
    entity_fn = get_entity_extractor(use_spacy=use_spacy)
    for _, r in corpus.iterrows():
        text = r["text"]
        ents = entity_fn(text)
        for e, typ, s, t in ents:
            ents_rows.append({
                "doc_id": r["doc_id"],
                "entity": e,
                "type": typ,
                "start": s,
                "end": t,
                "span": text[max(0, s-60):min(len(text), t+60)]
            })
    return pd.DataFrame(ents_rows)

def extract_relations(corpus: pd.DataFrame, entity_fn) -> pd.DataFrame:
    edges = []
    for _, r in corpus.iterrows():
        for sent in sentence_split(r["text"]):
            ents = entity_fn(sent)
            for i in range(len(ents)):
                for j in range(i+1, len(ents)):
                    e1, t1, *_ = ents[i]
                    e2, t2, *_ = ents[j]
                    edges.append({
                        "doc_id": r["doc_id"],
                        "head": e1, "type1": t1,
                        "tail": e2, "type2": t2,
                        "sentence": sent
                    })
    return pd.DataFrame(edges)
```

```
def build_graph(ents_df: pd.DataFrame, edges_df: pd.DataFrame) -> nx.Graph:
    G = nx.Graph()
    for _, e in ents_df.iterrows():
        G.add_node(e["entity"], type=e["type"])
    for _, ed in edges_df.iterrows():
        u, v = ed["head"], ed["tail"]
        ev = {"doc_id": ed["doc_id"], "sentence": ed["sentence"]}
        if G.has_edge(u, v):
            G[u][v].setdefault("evidence", []).append(ev)
        else:
            G.add_edge(u, v, evidence=[ev])
    return G

def detect_seed_entities(G: nx.Graph, query: str) -> List[str]:
    seeds = []
    q = (query or "").lower()
    for node in G.nodes():
        leaf = node.lower().split()[-1]
        if leaf in q:
            seeds.append(node)
    for node, data in G.nodes(data=True):
        t = data.get("type","").lower()
        if t and t in q:
            seeds.append(node)
    return list(dict.fromkeys(seeds))

def neighborhood_evidence(G: nx.Graph, seeds: List[str], hops: int = 1, max_spans:
int = 24):
    spans = []
    seen_edges = set()
    for s in seeds:
        if s not in G:
            continue
        nodes = nx.single_source_shortest_path_length(G, s, cutoff=hops).keys()
        for u in nodes:
            for v in G.neighbors(u):
                e = tuple(sorted([u, v]))
                if e in seen_edges:
                    continue
                seen_edges.add(e)
                data = G.get_edge_data(u, v) or {}
                ev_list = data.get("evidence", [])
                if ev_list:
                    rep = ev_list[0]
                    spans.append({"u": u, "v": v, "doc_id": rep.get("doc_id"),
"sentence": rep.get("sentence")})
                if len(spans) >= max_spans:
                    return spans
    return spans

def graph_rag(G: nx.Graph, query: str, hops: int = 1, max_spans: int = 24):
    seeds = detect_seed_entities(G, query)
    spans = neighborhood_evidence(G, seeds, hops=hops, max_spans=max_spans)
    return {"seeds": seeds, "spans": spans}

def assemble_prompt(query: str, seeds: List[str], spans: List[Dict]) -> str:
    ev_lines = [f"- ({s['doc_id']}) {s['sentence']}" for s in spans if
s.get("sentence")]
```

```
    return (
        "System: Answer using ONLY the evidence and cite (doc_id).\n"
        f"Query: {query}\n\n"
        f"Seeds: {', '.join(seeds) if seeds else '(none)'}\n\n"
        "Evidence:\n" + "\n".join(ev_lines) + "\n\nAnswer:"
    )

class DenseRetriever:
    def __init__(self, corpus_df: pd.DataFrame):
        self.df = corpus_df.reset_index(drop=True)
        self.vectorizer = None
        self.X = None
        self.enabled = _HAS_SKLEARN
        if self.enabled:
            texts = self.df["text"].fillna("").tolist()
            self.vectorizer = TfidfVectorizer(stop_words="english")
            self.X = self.vectorizer.fit_transform(texts)

    def topk(self, query: str, k: int = 5) -> List[Dict]:
        if not self.enabled:
            q_terms = set((query or "").lower().split())
            scored = []
            for i, r in self.df.iterrows():
                terms = set((r["text"] or "").lower().split())
                score = len(q_terms & terms)
                scored.append((score, i, r))
            scored.sort(reverse=True)
            return [{"doc_id": r["doc_id"], "text": r["text"], "score": s} for s,
i, r in scored[:k]]
        qv = self.vectorizer.transform([query or ""])
        sims = cosine_similarity(qv, self.X).ravel()
        idx = np.argsort(-sims)[:k]
        out = []
        for i in idx:
            r = self.df.iloc[i]
            out.append({"doc_id": r["doc_id"], "text": r["text"], "score":
float(sims[i])})
        return out

def decompose_query(query: str) -> List[str]:
    q = query or ""
    method_match = re.findall(r"\bMethod\s+[A-Z][A-Za-z0-9]*\b", q)
    wants_author = "author" in q.lower()
    wants_dataset = "dataset" in q.lower()
    subqs = []
    if method_match and wants_author and wants_dataset:
        m = method_match[0]
        subqs = [f"Which author proposed {m}?", f"Which dataset was used to
evaluate {m}?"]
    elif method_match and wants_author:
        m = method_match[0]
        subqs = [f"Which author proposed {m}?"]
    elif method_match and wants_dataset:
        m = method_match[0]
        subqs = [f"Which dataset was used to evaluate {m}?"]
    else:
        parts = [p.strip() for p in re.split(r"\band\b", q, flags=re.IGNORECASE) if
p.strip()]
        subqs = parts[:2] if parts else [q]
```

```
    return subqs

def answer_with_graph_rag(G: nx.Graph, subq: str, hops: int = 1, k: int = 5) ->
Dict:
    out = graph_rag(G, subq, hops=hops, max_spans=24)
    wants_dataset = "dataset" in subq.lower()
    wants_author = "author" in subq.lower()
    candidates = []
    for span in out["spans"]:
        for node in (span["u"], span["v"]):
            t = G.nodes[node].get("type", "")
            if wants_dataset and t == "DATASET":
                candidates.append((node, span["doc_id"], span["sentence"]))
            if wants_author and t == "AUTHOR":
                candidates.append((node, span["doc_id"], span["sentence"]))
    seen = set(); picks = []
    for c in candidates:
        if c[0] not in seen:
            seen.add(c[0]); picks.append(c)
        if len(picks) >= k:
            break
    return {"method": "graph_rag", "subq": subq, "answers": picks, "evidence":
out["spans"]}

def answer_with_dense_retriever(dr: DenseRetriever, subq: str, k: int = 5) -> Dict:
    hits = dr.topk(subq, k=k)
    return {"method": "dense", "subq": subq, "answers": [(h['text'], h['doc_id'])
for h in hits], "evidence": hits}

def synthesize_answer(query: str, hop_traces: List[Dict]) -> str:
    parts = []
    for i, hop in enumerate(hop_traces, 1):
        meth = hop.get("method"); subq = hop.get("subq"); answers =
hop.get("answers", [])
        if meth == "graph_rag":
            if answers:
                best = answers[0]
                parts.append(f"Hop {i}: {subq} → **{best[0]}** (evidence:
{best[1]})")
            else:
                parts.append(f"Hop {i}: {subq} → no match")
        else:
            if answers:
                txt, doc = answers[0]
                parts.append(f"Hop {i}: {subq} → context from {doc}")
            else:
                parts.append(f"Hop {i}: {subq} → no match")
    joined = "\n".join(parts)
    return f"Query: {query}\n{joined}\n"

def multi_hop_qa(G: nx.Graph, corpus: pd.DataFrame, query: str, hops: int = 2, k:
int = 5, prefer_graph: bool = True) -> Dict:
    subqs = decompose_query(query)
    dr = DenseRetriever(corpus)
    hop_traces = []
    for i, sq in enumerate(subqs, 1):
        if prefer_graph:
            ans = answer_with_graph_rag(G, sq, hops=min(hops,2), k=k)
        else:
```

```
            ans = answer_with_dense_retriever(dr, sq, k=k)
        hop_traces.append(ans)
    final_answer = synthesize_answer(query, hop_traces)
    return {"subquestions": subqs, "trace": hop_traces, "final": final_answer}

def download_ncei_storm_events_fl(out_csv: str, start_year: int = 2000, end_year:
int = 2025):
    instructions = f"""
NOAA NCEI Storm Events — Florida subset HOWTO
Bulk portal: https://www.ncei.noaa.gov/stormevents/ (CSV downloads)
Steps:
1) Download CSVs for {start_year}-{end_year} from the bulk page.
2) Concatenate and filter STATE == 'FLORIDA'.

Example:
    wget -c
"https://www.ncei.noaa.gov/pub/data/swdi/stormevents/csvfiles/StormEvents_details-
ftp_v1.0_dYYYY_c20250527.csv.gz"
    gunzip -f StormEvents_details-ftp_v1.0_dYYYY_c20250527.csv.gz

    python - <<'PY'
import pandas as pd, glob
files = sorted(glob.glob("StormEvents_details-ftp_v1.0_d*.csv"))
df = pd.concat((pd.read_csv(f) for f in files), ignore_index=True)
df_fl = df[df['STATE'].str.upper()=='FLORIDA'].copy()
df_fl.to_csv("{out_csv}", index=False)
print("Wrote Florida subset to: {out_csv}")
PY
"""
    doc_path = out_csv + ".HOWTO.txt"
    with open(doc_path, "w", encoding="utf-8") as f:
        f.write(instructions.strip())
    return doc_path

def openfema_disaster_declarations_fl(limit: int = 5000) -> pd.DataFrame:
    try:
        import requests
    except Exception:
        return pd.DataFrame()
    url = "https://www.fema.gov/api/open/v2/DisasterDeclarationsSummaries"
    params = {"$filter": "state eq 'FL'", "$top": limit, "$format": "json"}
    r = requests.get(url, params=params, timeout=60)
    if not r.ok:
        return pd.DataFrame()
    items = r.json().get("DisasterDeclarationsSummaries", [])
    return pd.DataFrame(items)

def run_pipeline(use_spacy: bool = True):
    corpus = ensure_corpus()
    ents_df = extract_all_entities(corpus, use_spacy=use_spacy)
    entity_fn = get_entity_extractor(use_spacy=use_spacy)
    edges_df = extract_relations(corpus, entity_fn)
    G = build_graph(ents_df, edges_df)
    return G, ents_df, edges_df, corpus

# -------------------------- Streamlit UI --------------------------

import streamlit as st
```

```
def app():
    st.set_page_config(page_title="Graph-RAG — Full Research App", layout="wide")
    st.title("Graph-RAG — Tracks A/B/C (Full Research Version)")

    # Sidebar
    st.sidebar.header("Controls")
    use_spacy = st.sidebar.checkbox("Use spaCy/scispaCy (if available)",
value=True)
    hops = st.sidebar.slider("Hop limit", 1, 2, 1)
    topk = st.sidebar.slider("Retriever top-k", 1, 10, 5)
    prefer_graph = st.sidebar.checkbox("Prefer Graph-RAG in Multi-Hop", value=True)
    show_graph = st.sidebar.checkbox("Show Graph Visualization", value=True)

    with st.spinner("Building graph from corpus..."):
        G, ents_df, edges_df, corpus = run_pipeline(use_spacy=use_spacy)

    tab_ans, tab_ev, tab_trace, tab_graph, tab_ablate, tab_florida = st.tabs(
        ["Answer Panel", "Evidence Panel", "Trace Panel", "Graph View", "Ablation",
"Florida Data"]
    )

    with tab_ans:
        st.subheader("Ask a Question")
        q = st.text_input("Query", "Which author proposed Method Y, and which
dataset did they evaluate it on?")
        mode = st.selectbox("Mode", ["Graph-RAG (Track A)", "Dense Baseline",
"Multi-Hop (Track B)"])
        if st.button("Run"):
            if mode == "Graph-RAG (Track A)":
                out = graph_rag(G, q, hops=hops, max_spans=24)
                prompt = assemble_prompt(q, out["seeds"], out["spans"])
                st.markdown("**Evidence-Constrained Prompt:**")
                st.code(prompt, language="text")
                st.session_state["_last"] = {"kind": "graph", "data": out,
"prompt": prompt}
            elif mode == "Dense Baseline":
                dr = DenseRetriever(corpus)
                hits = dr.topk(q, k=topk)
                st.markdown("**Top-k Context (Dense Baseline):**")
                for h in hits:
                    st.write(f"- ({h['doc_id']}) {h['text']}
[score={h.get('score','-')}]")
                st.session_state["_last"] = {"kind": "dense", "data": hits}
            else:
                mh = multi_hop_qa(G, corpus, q, hops=hops, k=topk,
prefer_graph=prefer_graph)
                st.markdown("**Final Answer (Multi-Hop synthesis):**")
                st.code(mh["final"], language="text")
                st.session_state["_last"] = {"kind": "multi", "data": mh}

    with tab_ev:
        st.subheader("Evidence")
        last = st.session_state.get("_last")
        if not last:
            st.info("Run a query in the Answer Panel.")
        else:
            if last["kind"] == "graph":
                spans = last["data"]["spans"]
                st.dataframe(pd.DataFrame(spans))
```

```
            elif last["kind"] == "dense":
                st.dataframe(pd.DataFrame(last["data"]))
            else:
                ev = []
                for hop in last["data"]["trace"]:
                    subq = hop["subq"]; method = hop["method"]
                    for e in hop.get("evidence", []):
                        row = {"hop_subq": subq, "method": method}
                        for k in ("doc_id","text","score","sentence"):
                            if k in e: row[k] = e[k]
                        ev.append(row)
                st.dataframe(pd.DataFrame(ev))

    with tab_trace:
        st.subheader("Multi-Hop Reasoning Trace")
        last = st.session_state.get("_last")
        if last and last["kind"] == "multi":
            st.json(last["data"])
        else:
            st.info("Run a Multi-Hop query in the Answer Panel.")

    with tab_graph:
        st.subheader("Graph Visualization")
        if show_graph and _HAS_MPL:
            try:
                pos = nx.spring_layout(G, seed=7)
                type_to_color =
{"METHOD":"#6aa84f","AUTHOR":"#3c78d8","DATASET":"#cc0000","PAPER":"#674ea7","METRI
C":"#e69138"}
                node_colors = [type_to_color.get(G.nodes[n].get("type",""), "#999")
for n in G.nodes()]
                fig = plt.figure(figsize=(7,5))
                nx.draw(G, pos, with_labels=True, node_color=node_colors,
node_size=900, font_size=9, edge_color="#bbb")
                st.pyplot(fig)
            except Exception as e:
                st.warning(f"Visualization unavailable: {e}")
        else:
            st.info("Enable 'Show Graph Visualization' in the sidebar, and ensure
matplotlib is installed.")

    with tab_ablate:
        st.subheader("Ablation Study")
        st.caption("Compares Baseline vs Graph-RAG vs Multi-Hop. Success metric =
any result found.")
        if st.button("Run small ablation"):
            rows = []
            queries = [
                "Which dataset was used to evaluate Method X?",
                "Which author proposed Method Y, and which dataset did they
evaluate it on?",
                "What metric was reported for Method X on Dataset D2?"
            ]
            for q_ in queries:
                for h in [1,2]:
                    dr = DenseRetriever(corpus)
                    base_hits = dr.topk(q_, k=topk)
                    base_ok = 1 if base_hits else 0
                    rows.append({"query": q_, "method": "baseline", "hops": 0, "k":
```

```
topk, "success": base_ok})

                    out = graph_rag(G, q_, hops=h, max_spans=24)
                    gr_ok = 1 if out["spans"] else 0
                    rows.append({"query": q_, "method": "graph_rag", "hops": h,
"k": topk, "success": gr_ok})

                    mh = multi_hop_qa(G, corpus, q_, hops=h, k=topk,
prefer_graph=True)
                    mh_ok = 1 if any(hh.get("answers") for hh in mh["trace"]) else
0
                    rows.append({"query": q_, "method": "multi_hop", "hops": h,
"k": topk, "success": mh_ok})

            df_ab = pd.DataFrame(rows)
            df_ab.to_csv(ABLATION_CSV, index=False)
            st.success(f"Ablation saved to {ABLATION_CSV}")
            st.dataframe(df_ab)

            if _HAS_MPL:
                try:
                    avg = df_ab.groupby(["method","hops"])
["success"].mean().reset_index()
                    fig = plt.figure(figsize=(6,4))
                    for method in avg["method"].unique():
                        sub = avg[avg["method"]==method]
                        plt.plot(sub["hops"], sub["success"], marker="o",
label=method)
                    plt.xlabel("Hops"); plt.ylabel("Success Rate");
plt.title("Ablation: Success vs Hops")
                    plt.legend(); plt.tight_layout()
                    st.pyplot(fig)
                except Exception as e:
                    st.warning(f"Plot skipped: {e}")

    with tab_florida:
        st.subheader("Florida Data Helpers")
        out_csv = os.path.join(DATA_DIR, "ncei_fl_storm_events.csv")
        howto_path = download_ncei_storm_events_fl(out_csv)
        st.markdown(f"- NOAA NCEI Storm Events HOWTO saved: `{howto_path}`")
        if st.button("Fetch FEMA Declarations for FL"):
            with st.spinner("Calling OpenFEMA API..."):
                df_fema = openfema_disaster_declarations_fl(limit=5000)
            if df_fema.empty:
                st.warning("No data returned (offline or requests not installed).")
            else:
                save_path = os.path.join(DATA_DIR, "fema_fl_declarations.csv")
                df_fema.to_csv(save_path, index=False)
                st.success(f"Saved FEMA FL declarations to {save_path}")
                st.dataframe(df_fema.head(50))

    cfg = {
        "data_dir": DATA_DIR,
        "corpus_csv": CORPUS_CSV,
        "graph_rag": {"hops": hops, "max_spans": 24, "use_spacy": use_spacy},
        "retriever": {"top_k": topk, "sklearn": _HAS_SKLEARN},
        "ui": {"show_graph": show_graph, "prefer_graph_in_multi": prefer_graph}
    }
    try:
```

```
        with open(RUNCFG_JSON, "w", encoding="utf-8") as f:
            json.dump(cfg, f, indent=2)
    except Exception:
        pass

# if __name__ == "__main__":
#     import sys
#     if any("streamlit" in s for s in sys.argv):
#         app()
#     else:
#         G, ents_df, edges_df, corpus = run_pipeline(use_spacy=True)
#         out = graph_rag(G, "Which dataset was used to evaluate Method X?",
hops=1)
#         print(assemble_prompt("Which dataset was used to evaluate Method X?",
out["seeds"], out["spans"]))
if __name__ == "__main__":
    import streamlit as st
    st.set_page_config(page_title="Graph-RAG Interactive App", layout="wide")

    st.title("▫ Graph-RAG Interactive Dashboard")

    tabs = st.tabs([
        "Answer Panel",
        "Evidence Panel",
        "Trace Panel",
        "Graph Visualization",
        "Ablation Study",
        "Florida Data"
    ])

    with tabs[0]:
        # from main_graph_rag import run_query
        query = st.text_input("▫ Enter Query", "Which dataset was used to evaluate
Method A?")
        if st.button("▶ Run Query"):
            answer, evidence, trace = run_query(query)
            st.subheader("▫ Final Answer")
            st.write(answer)
            st.subheader("▫ Evidence")
            st.write(evidence)
            st.subheader("▫ Reasoning Trace")
            st.write(trace)

    with tabs[1]:
        st.write("▫ Evidence details will appear here.")

    with tabs[2]:
        st.write("▫ Multi-Hop reasoning steps here.")

    with tabs[3]:
        import networkx as nx
        import matplotlib.pyplot as plt
        G = nx.Graph()
        G.add_edges_from([("Method A", "Dataset X"), ("Method A", "Paper Y")])
        fig, ax = plt.subplots()
        nx.draw(G, with_labels=True, node_color="lightblue", ax=ax)
        st.pyplot(fig)

    with tabs[4]:
```

```
    st.write("▫ Ablation study: accuracy vs. hops (to be filled).")

with tabs[5]:
    st.write("▫ Florida NOAA/FEMA data helper (to be integrated).")
```