



Towards Engineering Drones' Semantic Trajectories as Knowledge Graphs

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Geospatial Linked Data & UAVs

- Geospatial Linked Data (GLD) contribute to autonomous/unmanned aerial vehicles and (UAV) related services.
- Spatial knowledge graphs (KGs) can facilitate the processing and management of data related to moving objects' trajectories.



What is a *semantic trajectory*?

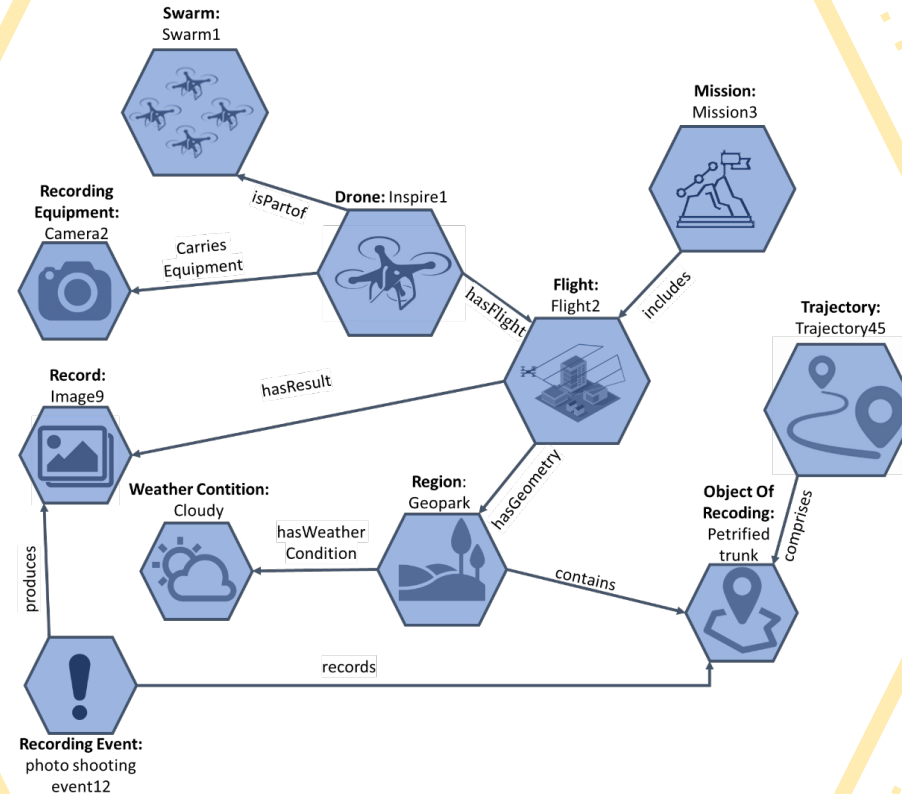
It is a trajectory:

- i) enriched and completed with additional information, beyond latitude, longitude, altitude, timestamp metadata, and/or
- ii) enhanced with several complementary segmentations



SW, KGs and Semantic Trajectories

SW technologies could
enhance a trajectory
and facilitate its
segmentation based on
semantic data.



KGs could be exploited for
the **representation and
processing** of Semantic
Trajectories.

Our research



- It is motivated by use cases related to drones' mission of recording specific POIs and ROIs, such as the GeoPark of petrified forest in Lesvos Island.
- Constitutes a KG-based approach for transforming trajectories of UAV drones into STs that can be effectively managed, visualized, and analyzed.

Main objectives

- 1 **modelling** of ST of drones and swarm of drones, their flights and recordings per mission.
- 2 **visualization and analysis** of the STs
- 3 **retrieval of semantic information** of flights/missions
- 4 **retrieval of records** which have been produced during different recording events of trajectories related to a flight/mission, based on parameters such as the type or location of recording events

Contribution of research

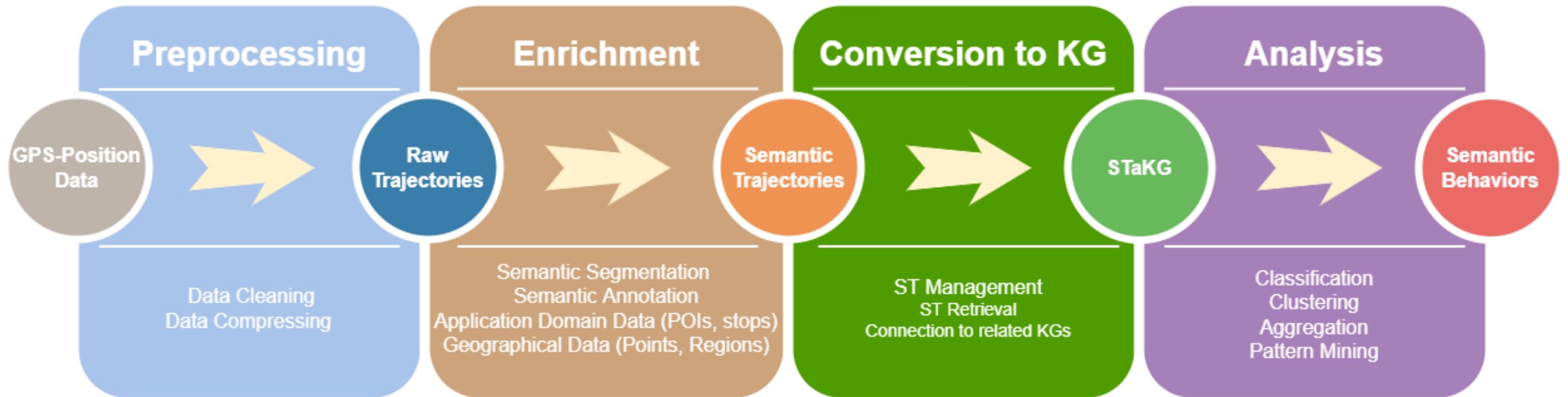
- 1 a **methodology** for the engineering of *semantic trajectories as KGs* (STaKG),
- 2 an integrated **toolset** for the management of KG-based semantic trajectories,
- 3 a **repository** of semantically annotated GIS recording missions and the corresponding produced documentation records.

STaKG Methodology

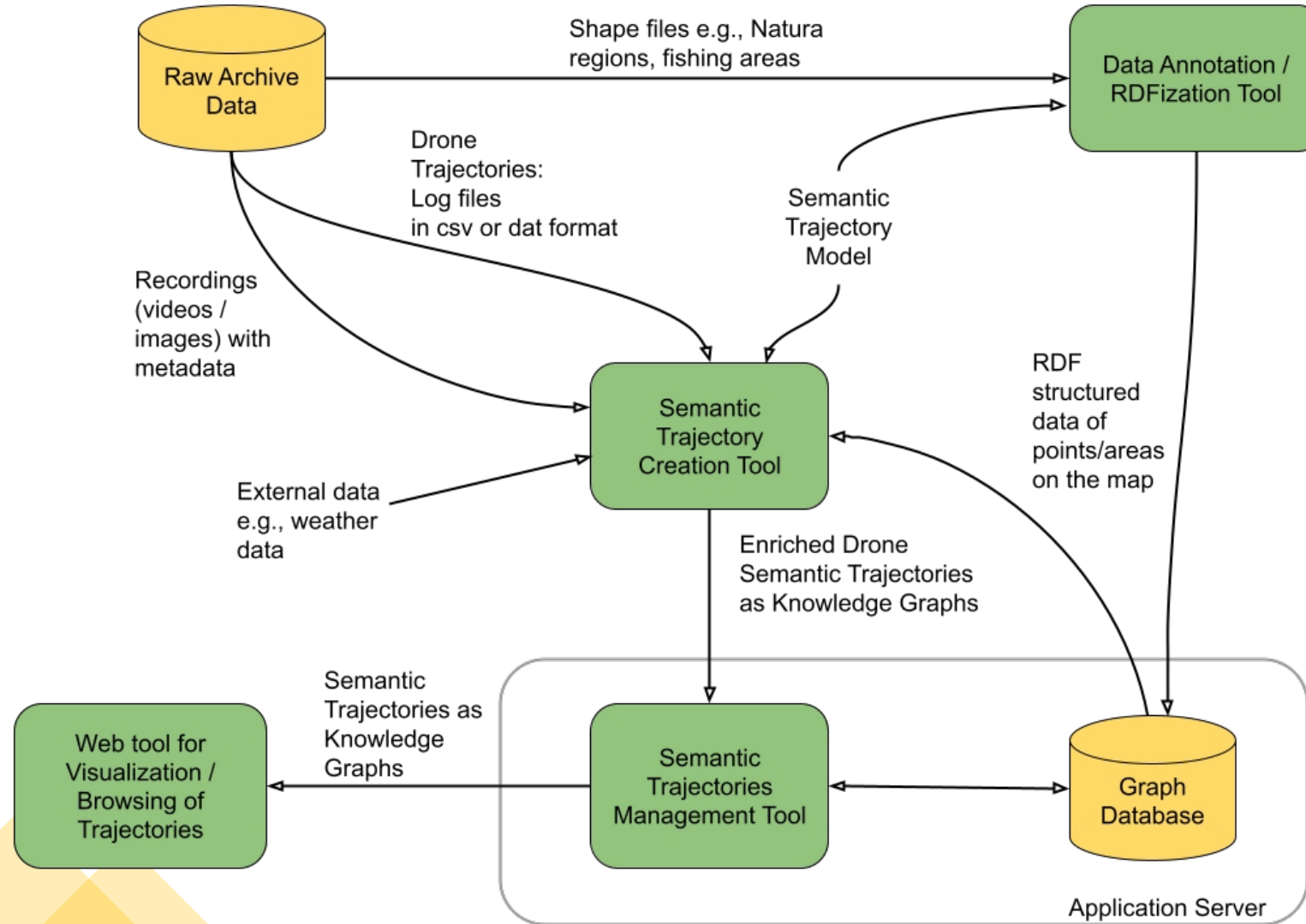
Hybrid (human-center/top-down and data-driven/bottom-up), collaborative and iterative approach for all phases of the ST as KG engineering lifecycle: from the specification of a STKG to its creation and exploitation.



STaKG pipeline processing



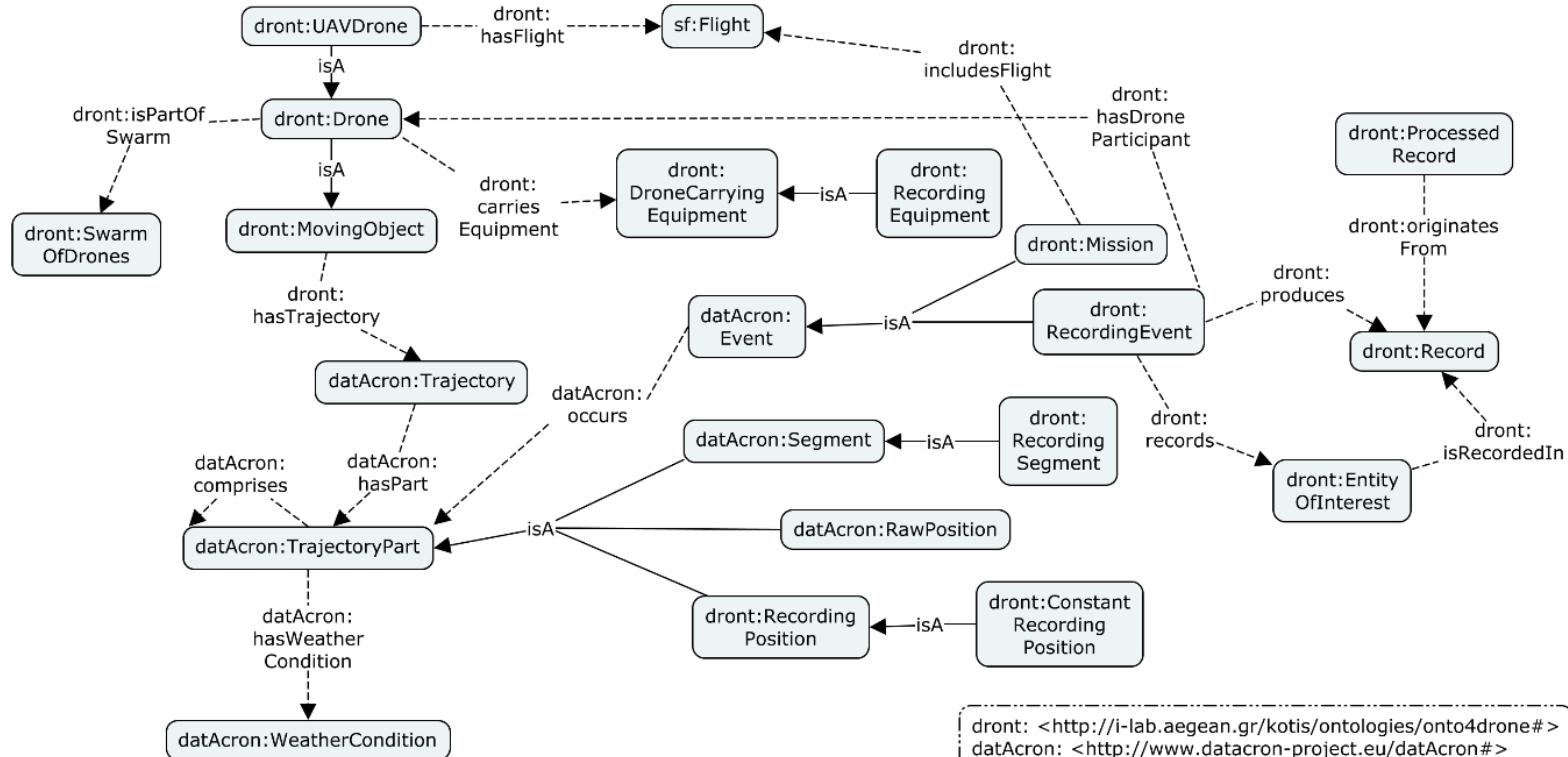
STaKG toolset



Data categories

- *flight data*
- *equipment data*
- *recording/mission data*
- *records data (aerial and terrestrial)*
- *geographic names and elements*
- *weather data*

Onto4drone (version 1.0.0)



dront: <http://i-lab.aegean.gr/kotis/ontologies/onto4drone#>
 datAcron: <http://www.datacron-project.eu/datAcron#>
 sf: <http://www.opengis.net/ont/sf#>

Notations

prefix:Class — subClass —> prefix: object Property

Onto4drone: <https://github.com/KotisK/onto4drone>

SPARQL Queries

SPARQL query:

```
#which flights of mission1 resulted in records that include the object of interest, petrified trunk
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dront: <http://i-lab.aegean.gr/kotis/ontologies/onto4drone#>
PREFIX datacron: <http://www.datacron-project.eu/datAcron#>
PREFIX opengis: <http://www.opengis.net/ont/sf#>
PREFIX sosa: <http://www.w3.org/ns/sosa/>
SELECT * WHERE {
    dront:m_001 dront:includesFlight ?flight .
    ?flight sosa:hasResult ?records .
    dront:petrifiedTrunk dront:isRecordedIn ?records.
}
```

flight	records
flight 001 of mission 001	photograph 001
flight 002 of mission 001	point cloud 001

Example query “which flights of mission1 resulted in records that include a specific object of interest, namely, a petrified trunk”.

SPARQL query:

```
#what are the weather conditions and temperature at the recording points while recording of the object of interest,
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dront: <http://i-lab.aegean.gr/kotis/ontologies/onto4drone#>
PREFIX datacron: <http://www.datacron-project.eu/datAcron#>
PREFIX opengis: <http://www.opengis.net/ont/sf#>
PREFIX sosa: <http://www.w3.org/ns/sosa/>
SELECT DISTINCT ?position ?weather ?temperature WHERE {
    dront:petrifiedTrunk dront:isRecordedIn ?record.
    ?rec_event dront:produces ?record.
    ?rec_event datacron:occurs ?position.
    ?position datacron:hasWeatherCondition ?weather.
    ?weather datacron:reportedMaxTemperature ?temperature
}
```

position	weather	temperature
position 002	weather condition 002 of position 002	"24"^^<http://www.w3.org/2001/XMLSchema#int>
position 001	weather condition 001 of position 001	"25"^^<http://www.w3.org/2001/XMLSchema#int>

Example query “what are the weather conditions and temperature at the recording points while recording a specific object of interest, namely, a petrified trunk”.

Next steps

Further exploitation of GeoSparql
classes and object properties

Addition of axioms and/or rules which
will support inferences useful for the
segmentation of trajectories based on
our use case

Development of STaKG toolset (merging
of STs, splitting and refinement of ST to
episodes.

Development of STaKG KB



Thank you!

Requirements (1/2)

R1: Identification of recording positions during a drone's flight.

R2: Segmentation of a drone's mission trajectory based on the flights that the mission consists of.

R3: Segmentation of a drone's flight trajectory based on the recording episodes that the flight consists of

R4: Correlation between the records and recording position of the drone's flight trajectory.

R5: Description of a whole mission of a drone, as well as the individual flights of the mission.

R6: Description of the drone, the equipment that it carries and the characteristics that may present in different instants of a flight.

R7: Specialization in mission/flights of drones for aerial recording/documentation of an object of interest.

R8: Description of the recording event that occurs during a flight of a drone, as well as the object recorded and the recording result.

Requirements (2/2)

R9: Description of the spatiotemporal positions and segments of the drone's flight.

R10: Enrichment of drone flight and trajectory with information about the weather conditions.

R11: Correlation of drone flight records with other existing (both aerial and terrestrial) records.

R12: Visualisation of individual drone's flights (in terms of trajectories, positions and episodes).

R13: Visualisation of flights clusters (e.g., per mission).

R14: Visualisation-visual comparison of different flights or/and missions.

R15: Querying and retrieval of contextual data about flights and missions trajectories, as well as individual positions and episodes (e.g., retrieval of records for a position, retrieval of weather conditions during a recording episode).

Competency Questions (1/2)

CQ1: Which are the trajectories of missions that include lidar recording of object "X"?

CQ2: Which are the recording positions of missions that include lidar recording of object "X"?

CQ3: Which photo records were produced during mission "X"?

CQ4: Which missions resulted in photo records?

CQ5: Which are the recording positions of flight "X"?

CQ6: Which records were taken from the recording position "X"?

CQ7: At which part of a flight trajectory recording occurred?

Competency Questions (2/2)

CQ8: What is the weather (conditions) at Lat X, Long Y, during the flight F of mission M?

CQ9: Which flights of mission M1 and mission M2 are overlapping?

CQ10: Which missions between date d1 and date d2 are overlapping (or related or are similar or...)?

CQ11: What is the number of drones of a specific swarm and the number of flights/trajectories for a specific mission at specific date and lat/long?

CQ12: Which are the recording events that are 100m near the recording event "X"?

CQ13: Which are the recording events that are 100m near the object "X"?