AI in Greece: The Case of Research on Linked Geospatial Data

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Introduction

Artificial Intelligence has been an active research field in Greece for over forty years, and there are more than thirty AI groups throughout the country covering almost all subareas of AI. One milestone for AI research in Greece was in 1988, when the *Hellenic Artificial Intelligence Society (EETN)* was founded as a non-profit, scientific organization devoted to organizing and promoting Artificial Intelligence research in Greece and abroad. EETN is an affiliated society of the European Association for Artificial Intelligence (EurAI – formerly ECCAI). One of the many roles of EETN is the organization of conferences, workshops, summer schools and other events, with the *Hellenic Conference on Artificial Intelligence (SETN)*, being the most prominent forum for Greek and international AI scientists to present original and high-quality research on emergent topics of Artificial Intelligence. The first SETN was organized in 1996 at the University of Piraeus, and since 2002, the conference is organized biennially. For instance, the SETN-2016 conference was co-organized by EETN and the Aristotle University of Thessaloniki in May 2016, presenting high quality research work in AI (the acceptance ratio for full papers was below 33%) and attracting international attention, with more than 120 participants from Greece and abroad joining the event; while SETN 2018 will take place at the University of Patras from July 9 to 15, 2018 (http://setn2018.upatras.gr/). Similarly, the *Hellenic Artificial Intelligence Summer School (HAISS)*, is organized biennially under the auspices of EETN.

Current Lines of AI Research in Greece

At present, there exist 31 research groups affiliated with 15 Greek Universities and Research Institutes that house a large number of researchers, postgraduate and PhD students working on various topics related to AI. More specifically, during the past few years, research in AI has been focusing on the following topics:[1] *Machine Learning and Data Mining, Uncertainty in AI, Natural Language Processing, Computer Vision, Robotics, Multi-Agent and Agent-Based Systems, Constraint Satisfaction, Planning and Scheduling, Knowledge Representation and Reasoning.* In the current article, we will focus on the latter; and more specifically, on *Linked Geospatial Data,* an exciting domain with many applications, and one pioneered by the team of Professor Manolis Koubarakis. But let us begin with a quick history lesson first.

[1] Some research articles on topics that have been pursued by Greek AI researchers in recent years can be found at http://www.eetn.gr/index.php/members/research-areas-groups

Some History (1968 to today)

Knowledge Representation is an area of research in which Greece has had a strong presence for many years. This work has been influenced a lot by the work of Professor John Mylopoulos at the University of Toronto during the 70s and 80s. Mylopoulos (who is also an honorary EETN member) supervised a number of students that ended up in Greek Universities and "preached the gospel" to younger students entering the field of AI. He was especially influential in the work done at the Institute of Computer Science, Foundation of Research and Technology – Hellas (ICS-FORTH), which is based in Heraklion, Crete. Since 1985, Mylopoulos and the people in ICS-FORTH collaborated in a number of ESPRIT projects that had a strong knowledge representation component. A core contribution of this research has been the development of the knowledge representation language Telos and its application to requirements modeling for software engineering. The arrival of the Semantic Web with the visionary paper of Tim-Berners Lee (the 2016 Turing Award winner), Jim Hendler and Ora Lassila in the Scientific American in 2001, found the Institute of Computer Science with a very strong Knowledge Representation team. That team went on to become one of the most influential ones in the Semantic Web area in Europe, especially through the development of RQL, one of the first query languages for the Resource Description Framework (RDF). RQL has been influenced by Telos which had one of the closest representational frameworks to RDF (for a detailed discussion, younger readers may want to consult [CJK+09]).

Professor Manolis Koubarakis was one of the young researchers that worked on Telos under the supervision of John Mylopoulos. He completed an M.Sc. in Computer Science at the University of Toronto in 1988. Koubarakis returned to Greece in 1992 and did his PhD in constraint databases, a research area that had been pioneered in 1990 by another Greek, the late Paris Kanellakis, a professor at Brown University. He then went on to a career in the United Kingdom (Imperial College and University of Manchester), Technical University of Crete, and the National and Kapodistrian University of Athens where he is now based. He was elected as a Fellow of the European Association for Artificial Intelligence (EurAI) in 2015. His *"Knowledge Representation, Reasoning and Analytics (KRR&A)"* group (http://kr.di.uoa.gr/) in Athens has done lots of pioneering work on linked geospatial data, and constitutes a point of reference for this line of research internationally. As such, the rest of this article focuses on surveying that work.

Linked Geospatial Data work by the KRR&A group (2010-today)

Lots of geospatial data has become available at no charge in Europe and the US recently, and there is a strong push for more open geospatial data. This data includes data from volunteer mapping efforts such as OpenStreetMap, gazeteers such as GeoNames, national geographical data made available in government data portals (for example, in https://data.gov.uk/) and Earth Observation (EO) data from the satellite program Landsat of the US and the Copernicus program of the European Commission.

Linked data is a research area which studies how one can make RDF data available on the Web, and interconnect it with other data with the aim of increasing its value. In the last few

years, linked geospatial data has received a lot of attention as researchers and practitioners have started tapping the wealth of geospatial information available on the Web. As a result, the linked open data cloud has been rapidly populated with geospatial data.

The KRR&A group has been the first group internationally to introduce the linked data paradigm to the EO domain, and to develop prototype applications that were based on transforming Earth Observation data into RDF and combining them with other kinds of open linked data. Examples of such applications include wildfire monitoring and burnt scar mapping, building semantic catalogues for EO archives, precision farming, change detection using satellite images, real-time maritime situation awareness and various environmental services. Probably the best example of an application developed by the group is the wildfire monitoring application (see Figure 1). It has been available on the Web since 2012 and has been the basis for the operational FIREHUB service deployed at the National Observatory of Athens (http://195.251.203.238/seviri/). FIREHUB was awarded the Best Service award in the Copernicus Master's competition of 2014.

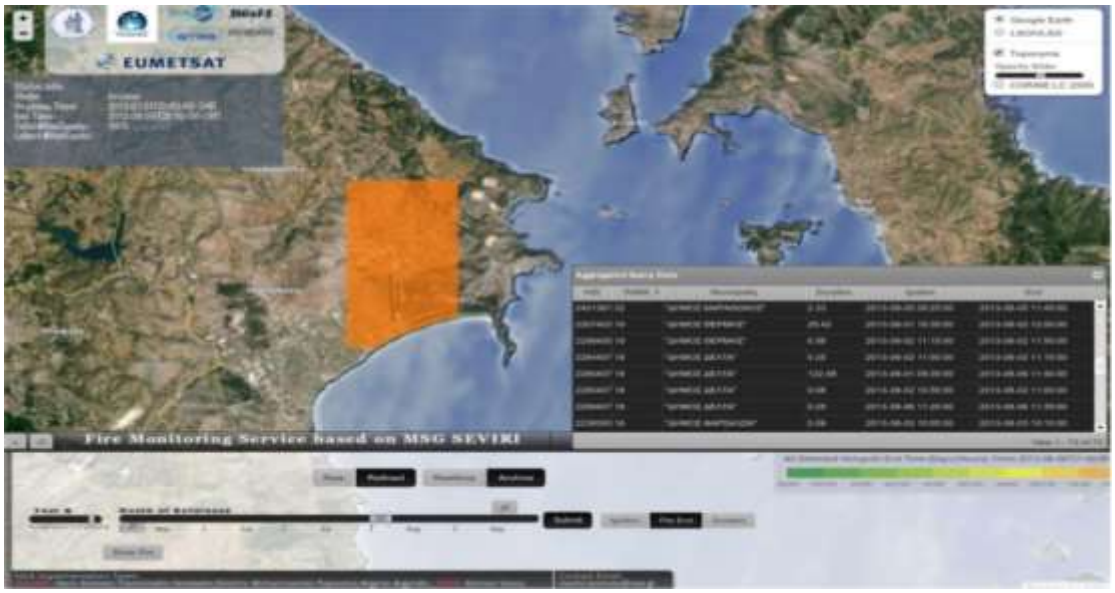

Figure 1: The FIREHUB service

The work of the KRR&A group concentrated on the whole life cycle of linked open EO data and its combination with linked geospatial data is shown in Figure 2 below.

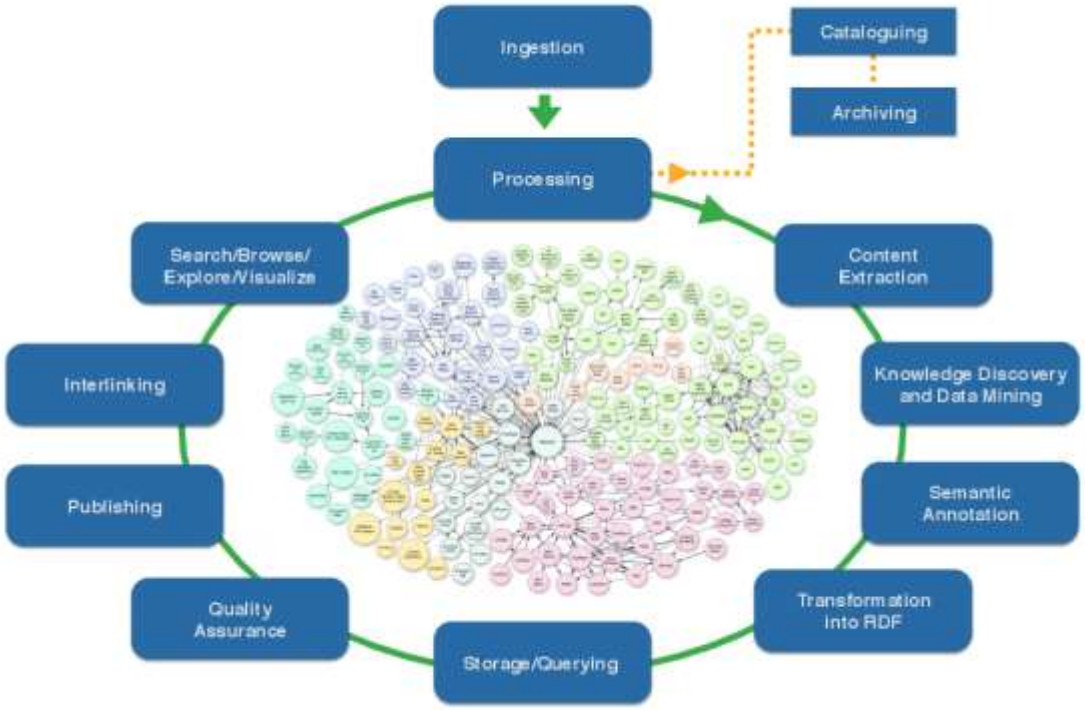

Figure 2: The lifecycle of linked open EO data

The technical challenges of various phases of this life-cycle have been addressed with the development of open source tools that represent today's state of the art in the area of linked geospatial data. Perhaps the most well-known such tool is **Strabon** (http://strabon.di.uoa.gr), a spatiotemporal RDF store. Strabon extends the well-known RDF store Sesame and uses PostgreSQL as the backend spatially- and temporally-enabled DBMS. One of the query languages supported by Strabon is the Open Geospatial Consortium standard GeoSPARQL, an extension of the well-known RDF query language SPARQL with vocabulary for querying geospatial data. As shown by the experiments in [GKK13], Strabon is currently the most functional and performant geospatial and temporal RDF store available. Application developers that use Strabon also use **GeoTriples** (http://geotriples.di.uoa.gr/), a tool that enables them to transform data from many popular geospatial data formats into RDF.

It is often the case that geospatial data is stored in geospatial relational databases (e.g., PostGIS or SpatialLite) and it is not available as linked data. When these databases get frequently updated and/or are very large, domain experts are discouraged from transforming the data into RDF and store it in a triple store such as Strabon. For this reason, the KRR&A group developed the system **Ontop-spatial** (http://ontop-spatial.di.uoa.gr/), which is the *first* geospatial Ontology-Based Data Access system. This is a very interesting contribution, especially in the light of many published papers on spatial description logics and geospatial databases. Ontop-spatial allows domain users to leave their data in geospatial databases and it enables on-the-fly GeoSPARQL-to-SQL translation using ontologies and mappings. The experimental evaluation of Ontop-spatial published in [BK16]

has shown that this approach is not only simpler for the users as it does not require materialization of data, but also more efficient in terms of query response time when compared with state-of-the-art geospatial RDF stores such as Strabon or even commercial systems.

Finally, the KRR&A group has made an important contribution to the state of the art in visualizing geospatial and temporal linked data by developing the tool Sextant (http://sextant.di.uoa.gr). Sextant is a Web-GIS for linked data. It can be used to produce maps by combining geospatial data from GeoSPARQL endpoints and well-known GIS file formats. Figure 3 shows a screenshot of Sextant.

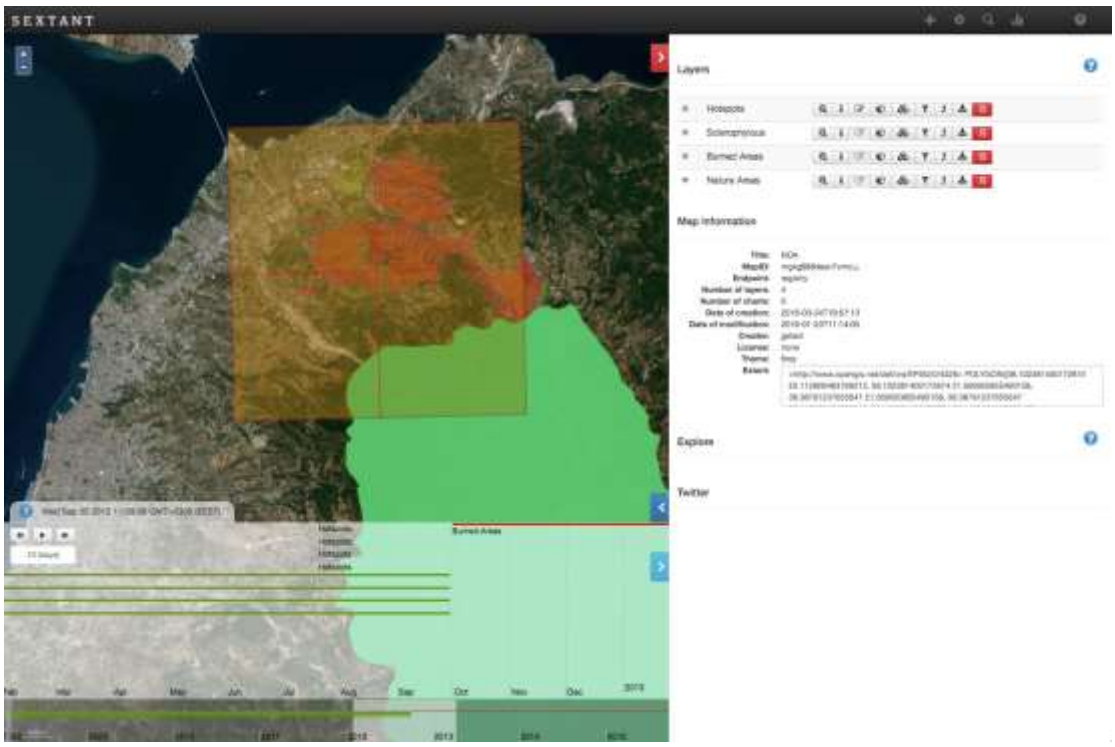

Figure 3: Visualizing a burned area map with Sextant

The above paragraphs summarize the progress that has been made by the KRR&A group in the area of linked geospatial data in the last seven years. A more detailed presentation can be found in [KBP+17]. That work has been supported generously by the European Commission through six research projects, and the Greek government through the prestigious research excellence grant "ΑΡΙΣΤΕΙΑ" ("Excellence") for Prof. Koubarakis. The current work of the group concentrates on two topics: *(i)* making the above tools scale to big data by utilizing big data technologies such as Apache Spark, and *(ii)* question answering for geospatial and temporal knowledge graphs.

Conclusions

A vibrant AI research community does exist in Greece; one that produces original and high-impact work such as the one discussed above. There are, in fact, many other ongoing ``AI research success stories'' in Greece---something also evident from the fact that several AI research institutes with an internationally renowned research track record operate in the

country (e.g., Institute of Informatics and Telecommunications at the National Center for Scientific Research "Demokritos", Institute of Language and Speech Processing at Athena Research and Innovation Center); and from the number of Greek researchers-EETN members that have been appointed *EurAI Fellows* (five in the last fifteen years). EETN strives to help keep up this momentum, and to assist young AI researchers—e.g., by providing them with scholarships to attend and present their work to AI conferences worldwide. Moreover, a new institution recently put forward by EETN is *Technothesis,* an attempt to pair undergraduate or graduate AI students with EETN members that act as scientific mentors and thesis committee members, and who are not necessarily located at the student's host university. Finally, EETN is active in popularizing Greek AI research, and inciting the interest of both university students and high school pupils to the field, via organizing or co-organizing AI discussion forums, exhibitions, and competitions.

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