MASTER

Multiple ASpect TrajEctoRy management and analysis

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ACRONYM LIST

MASTER	Multiple Aspects Trajectory Management and Analysis
ICT	Information and Communication Technologies
ISTI	Istituto di Scienza e Tecnologie dell'Informazione "A. Faedo"
CNR	Consiglio Nazionale delle Ricerche
UNIVE	Ca' Foscari University of Venice
UVSQ	University of Versailles Saint-Quentin
UPRC	University of Pireaus Research Center
HUA	Harokopio University of Athens
PUC	Pontificial University of Rio de Janeiro
UFC	Federal University of Ceará
DAL	Dalhousie University
THIRA	Municipality of Thira
ER	Experienced Researcher
ESR	Early Stage Researcher
AIS	Automatic Identification System (AIS)

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1. INTRODUCTION

According to the GA Annex I Part A, this deliverable "reports on the last activities on T3.2 and is a complete report of the activities of T3.1 and T3.2". For this reason, we include material from D3.1 which was the preliminary report on the activities of T3.1 and T3.2

The objective of Tasks 3.1 is to "study how multi-modal aspects of holistic trajectories can be computed by exploiting external information sources from private datasets and knowledge bases, user-generated content and Linked Open Data". This task started at M1 and finished at M24. Objectives of this task have been fully achieved as detailed in the deliverable D3.1 and reported in Section 2.

The objective of Task 3.2 is "to provide the requirements for storing holistic trajectories and processing efficiently complex queries over them. The goal is designing and implementing a unifying data access layer dealing with the inherently heterogeneous nature of holistic trajectories, a building block of any analytical process." This task started at M6 and finished at M60. The objectives of this task have been fully achieved as described in Section 2.

The role of CNR researchers has been to work on Task 3.1 *Holistic trajectory enrichment methods* in order to define a visual tool to enrich trajectories with semantic information. CNR has contributed on Task3.2 *Holistic trajectories data management* by designing a conceptual and logical model for multiple aspect trajectories in collaboration with UFSC, and by drawing a unifying access layer, in collaboration with UFC, PUC and UFSC to include the different datasets and methods shared and implemented in the consortium.

The role of UNIVE researchers has been to work on Task 3.2 *Holistic trajectories data management*, in collaboration with DAL, in order to create a model of holistic trajectories regarding fishing vessels and a predictive model for an indicator of the fishing resources exploitation, i.e., Catch Per Unit Effort. The model developed in this Task contributes to T5.2, WP5, to the sea monitoring scenario and reported in D5.2. Indeed, it is worth mentioning that an objective of WP3, reported below, is the "development of novel techniques of semantic enrichment to properly build holistic trajectories thus enabling the analysis carried out in WP4 and exploited in the application scenarios of WP5." Furthermore, UNIVE research activities coped with the issue of sparse datasets in collaboration with UFC.

The role of UPRC researchers has been to work on Task 3.2 *Holistic trajectories data management* in order to study and propose efficient methods to process complex queries over holistic trajectories.

The role of PUC researchers has been to share their great experience with databases and trajectories and in particular their knowledge about Linked Open Data and RDF (Resource Description Framework).

The role of DAL researchers has been to provide their expertise on machine learning for trajectories maritime data analysis and to collaborate in the development of methods to segment trajectories and enrich them with semantic information. This collaboration produced three joint publications between UNIVE and DAL that is discussed later in this document as publications [5, 6, 8].

The role of UFC researchers has been to study possible datasets of trajectories and external information sources that could be used for enriching these trajectories.

The research activities carried out during these 60 months of the project for these tasks have produced 8 publications which are briefly presented in the following.

Task 3.1 copes with the definition of methods to enrich trajectories with semantic information in order to build holistic trajectories. In fact, most of the trajectory datasets only record the spatio-temporal positions of moving objects, thus lacking semantics. The work presented in [1] by project partners describes a visual-analytics-based platform, called VISTA. VISTA objective is to assist the user in the trajectory annotation process. A session manager creates a tagging session selecting the trajectory data and the semantic contextual information from external information sources, that can be private databases or knowledge bases, user-generated content or Linked Open Data. The VISTA platform also supports the creation of several features that help the tagging users in identifying the trajectory segments that have to be annotated. A distinctive feature of VISTA is the visual analytics functionalities that support the users in exploring and processing the trajectory data, the associated features, and the semantic information for a proper comprehension of how to properly label trajectories.
Still in the line of offering a system supporting the user in the complex process of building multiple aspect trajectories from heterogeneous data sources and with different semantic aspects, the system MAT-Builder has been proposed by project partners in [7]. Some advantages of MAT-Builder are modularity and extensibility, thus allowing developers to add new aspects, external data sources, and functionalities. It is important to point out that MAT-Builder has been designed aiming at reusing functionalities provided by existing mobility data management libraries, such as GeoPandas, Scikit-mobility and PTrail.

Another interesting result still related to the activities of Task 3.1 specifically on user generated content, is the publication [2]. Here project partners present a methodology for analyzing user location information in order to identify user habits. To achieve this, user's GPS logs, provided through his/her Google location history, are analyzed. The locations where user usually spends more time are detected, and after identifying the user's frequently preferred transportation types and trajectories, the type of places the user visits in a regular base (such as cinemas, restaurants, gyms, bars, etc,) are found. Finally, the habits the user is most likely to have are extracted. These pieces of information can be very useful to enrich our trajectories and therefore produce multiple aspects trajectories.

Finally, another relevant publication for Task 3.1 concerns trajectory segmentation, i.e., splitting trajectories into homogeneous segments based on some criteria. This is a fundamental step in order to find a meaningful annotation to be associated with trajectory segments. In paper [3] project partners propose a semi-supervised approach for manually labelling a small set of trajectories with meaningful segments and, from this set, the method infers in an unsupervised way the segments of the remaining trajectories. The main advantage of this method compared to pure supervised ones is that it reduces the human effort to label the number of trajectories to be enriched.

A publication resulting from project activities of Task 3.2 addresses the storage and the efficient processing of holistic trajectories. The main contribution of the paper [4] from researchers of UFSC and CNR is the definition of a conceptual and logical model for multiple aspect trajectories. This work introduces the concept of *multiple aspect trajectory* that generalizes the state-of-the-art semantic trajectory definition into a more complex but realistic trajectory based on the notion of *aspect*. Different kinds of aspects are defined. When an aspect varies frequently during the object movement, the aspect with its semantic meaning is associated with each trajectory point and it is called *volatile aspect* (VA). When an aspect does not change during an entire trajectory, it is called a *long term* aspect (LTA), and is associated with the multiple aspect trajectory. A conceptual data model for

multiple aspect trajectories with a large expressive power is provided, that combines simplicity with a powerful representation of different types of moving objects and a variety of spatial, temporal and semantic aspects that are relevant to a vast range of applications. Then a conversion of the conceptual data model into a logical schema in the Resource Description Framework (RDF) standard to be adherent to the *Semantic Web Linked Open Data* standards is given. It is also discussed the usage of a triplestore based on NoSQL databases for maintaining RDF data, since these databases represent a new and efficient technology to maintain and query trajectory data.

Other publications related to Task 3.2 obtained from the collaboration between UNIVE and DAL are [5, 6, 8]. Here we exploit a unique, high-value spatio-temporal dataset that results from the fusion of three data sources: trajectories from fishing vessels (obtained from terrestrial Automatic Identification System, or AIS, data feed), the corresponding fish catch reports (i.e., the quantity and type of fish caught), and relevant environmental data. The result of that fusion is a set of semantic trajectories describing the fishing activities in North-western Adriatic Sea over two years. Some early results from an exploratory analysis of these semantic trajectories, as well as from initial predictive modeling using Machine Learning are presented in [5]. The goal is to predict the Catch Per Unit Effort (CPUE), an indicator of the fishing resources exploitation useful for fisheries management. Then the analysis has been extended to four years and in [6] different techniques to distribute the fish caught by the fishing vessels along their trajectories have been formalised and compared. Moreover, a prototype implementation of the spatio-temporal database has been provided. It has been used MobilityDB, an open source geospatial trajectory data management and analysis platform, specifically developed to support the representation and the analysis of moving objects. In the journal [8] all the phases of the database creation, starting from the raw data and proceeding through data exploration, data cleaning, trajectory reconstruction and semantic enrichment have been described in detail and an in-depth experimental analysis of a broad range of predictive models has been conducted in order to predict CPUE and evaluate their performance using several measures. According to WP3 objectives, these publications join together activities concerning two different WPs: WP3 (Task 3.2) and WP5 (Task 5.2). The papers describe the set of holistic trajectories we built by exploiting the model developed in Task 3.2 (described in the current deliverable) and the dataset used from the Sea Monitoring scenario and how we coped with some application questions of such a scenario (described in Deliverable D5.2).

2. WP3 OBJECTIVES AND TASKS

From GA Annex I Part A. WP3 Objective: This work package will focus on the development of novel techniques of semantic enrichment to properly build holistic trajectories thus enabling the analysis carried out in WP4 and exploited in the application scenarios of WP5. This WP will investigate data management issues including methods to store and query holistic trajectories by considering Big Data and Privacy issues. Training is embedded in each secondment as seconded ESRs will attend seminars and courses at the hosting institution and includes the events Summer School and Dagstuhl Seminar.

WP3 consists of the following tasks:

T3.1: Holistic trajectory enrichment methods (Leader CNR) (M1-M24)

T3.2: Holistic trajectories data management (Leader UNIVE) (M6-M60)

T3.3: Privacy issues in holistic trajectories (Leader UVSQ) (M6-M60)

T3.4: Big Data solutions for holistic trajectories (Leader HUA) (M6-M60)

T3.5: Training on holistic trajectories building and management (Leader CNR) (M1-M60)

The work developed in preparing this deliverable is connected to the secondments linked to WP3 and specifically for Tasks 3.1 and Task 3.2. Tasks T3.3 and T3.4 are presented in deliverables D3.2. Results of task T3.5 on training will be presented in Deliverable D2.2 due on M70 (31/12/2023) called "Training and Networking activities report and material".
The objective of Task 3.1 (M1 – M24) has been mainly reached with secondments of European Partners to DAL, UFC, PUC, UFSC and from third country partners UFC and DAL to CNR. The task finished at M24 and the objective of this task has been fully achieved.

The objective of Task 3.2 (M6 – M60) has been achieved with secondments of European Partners to DAL, UFC, PUC, UFSC and from UFC and DAL to CNR. The task finished at M60 and the objective of this task has been fully achieved.

The list of secondments linked to Task T3.1 and T3.2 are reported in Table 1 below. The total PM linked to Task 3.1 and to Task 3.2 are respectively 8,63 and 8,76.
The activity on these tasks produced 8 publications reported in the Publications section of this document and briefly described in the introduction.

Table 1 - List of Secondments linked to T3.1 and T3.2

RD #	Second ment#	Fellow ID	Profile	Secondee Name	Sending Institution	Hosting Institution	From	To	PM	Task
1	78, 80	1	ER	Stan Matwin	Dalhousie University	Consiglio Nazionale Delle Ricerche	14-03-2018 13-03-2019	13-04-2018 14-04-2019	2.07	T3.1
2	77	2	ER	Leopoldo Soares de Melo Junior	Universidade Federal do Ceará	Consiglio Nazionale Delle Ricerche	01-03-2018	31-08-2018	5.00	T3.1
9	22	11	ER	Alessandra Raffaetà	Università Ca' Foscari Venezia	Universidade Federal do Ceará	08-08-2018	08-09-2018	1.03	T3.2
10	25	12	ER	Marta Simeoni	Università Ca' Foscari Venezia	Dalhousie University	27-07-2018	29-08-2018	1.10	T3.2
15	1	4	ER	Chiara Renso	Consiglio Nazionale Delle Ricerche	Dalhousie University	26-09-2018	08-10-2018	0.43	T3.1
22	8	4	ER	Chiara Renso	Consiglio Nazionale Delle Ricerche	Universidade Federal De Santa Catarina	11-03-2019	06-04-201	0.9	T3.2
23	12	6	ER	Muntean Cristina Ioana	Consiglio Nazionale Delle Ricerche	Pontifical Catholic University of Rio de Janeiro	11-03-2019	03-04-2019	0.8	T3.1
24	7	4	ER	Chiara Renso	Consiglio Nazionale Delle Ricerche	Universidade Federal do Ceará	16-06-2019	25-06-2019	0.33	T3.1
30	11	22	TECH	Beatrice Rapisarda	Consiglio Nazionale Delle Ricerche	Universidade Federal De Santa Catarina	26-10-2019	16-11-2019	0.73	T3.2

33	38	25	ESR	Marios Vontas	University Of Piraeus Research Center	Faculdades Catolicas Associacao Sem Fins Lucrativos	06-11-2019	05-12-2019	1	T3.2
31	39	23	ESR	Nikolaos Koutroumanis	University Of Piraeus Research Center	Faculdades Catolicas Associacao Sem Fins Lucrativos	06-11-2019	05-12-2019	1	T3.2
43	104	22	TECH	Beatrice Rapisarda	Consiglio Nazionale Delle Ricerche	Universidade Federal do Ceará	24-06-2022	23-07-2022	1	T3.2
44	109	22	TECH	Beatrice Rapisarda	Consiglio Nazionale Delle Ricerche	Faculdades Catolicas Associacao Sem Fins Lucrativos	10-08-2022	09-09-2022	1	T3.2
45	16	4	ER	Chiara Renso	Consiglio Nazionale Delle Ricerche	Faculdades Catolicas Associacao Sem Fins Lucrativos	10-08-2022	09-09-2022	1	T3.2

TASK 3.1: HOLISTIC TRAJECTORY ENRICHMENT METHODS (LEADER: CNR) (M1-M24).

According to the GA Annex I Part A the objective of Task 3.1. is "to study how multi-modal aspects of holistic trajectories can be computed by exploiting external information sources from private datasets and knowledge bases, user-generated content and Linked Open Data"

As already described in D3.1 task activities have been carried out during 6 secondments reported in Table 1: #77, #78, #80, #1, #12 and #7 executed by secondees Leopoldo Soares de Melo Junior (UFC), Stan Matwin (DAL), Chiara Renso (CNR) and Muntean Cristina Ioana (CNR) for a total of 8,63 PM.

During Secondment #77, Leopoldo Soares de Melo Junior (UFC), seconded at CNR, carried out research focused on Task 3.1 (first 5 months) and Task 3.4 (remaining 6,63 months, therefore reported in D3.2). First, he studied possible datasets of trajectories and external information sources or private datasets that could be used for enriching these trajectories. For example, he took into consideration publicly available trajectories datasets, like the GeoLife dataset (see the GA Annex I Part B page 13) and how to enrich them with labels. He observed that these datasets are typically unbalanced since they are labelled in a very imbalanced way.

During Secondments #78 and #80, Stan Matwin (DAL), seconded at CNR, collaborated with CNR researchers to better understand the AIS data and the maritime research problems that DAL partner is currently facing on. In particular, they addressed the issue of how to enrich semantically these data. They first discussed and developed research on trajectory segmentation. Segmentation is a basic step in enriching trajectories since the most significant part of a trajectory has to be identified – the segment - to be later enriched with additional data sources. This collaboration brought a joint publication listed in the Publications section as [3]. In a second period, the research work of Prof. Matwin with CNR researchers focused on the study of a tool for supporting the user in segmenting and annotating trajectories that brought the creation of the system VISTA, resulting in the publication [1] and also linked to the work of Secondment #1 of Chiara Renso described below.

During Secondment #1, Chiara Renso (CNR), seconded at DAL, discussed the ongoing activities between DAL and CNR and how to continue this collaboration. Together with Prof. Matwin and Amilcar Soares Junior they revised the VISTA platform and discussed the kind of publication to prepare (a demo) in the following months for submission to a major conference. This resulted in the paper [1] published at the International Conference on Extended DataBase Technology conference in 2019.

During Secondment #12, Muntean Cristina Ioana (CNR), seconded at PUC, put the basis for a potential collaboration with Prof. Marco Casanova. By exploiting his vast experience with databases and trajectories, the idea was to work on the application of machine learning algorithms to Linked Open Data and in particular to the Linked Open data format RDF (resource description framework) since RDF data can be used to enrich trajectory data. The focus of this work was on ranking the paths between couples of entities in an RDF graph in order to give the best or most interesting path between two entities. The objective is to apply learning to rank algorithms in order to rank similarity paths between two entities in an RDF graph.

During Secondment #7, Chiara Renso (CNR), seconded at UFC, started a collaboration to exploit Human NERD, a tool developed by UFC, to build holistic trajectories, for example by taking into account social media like Twitter and by using text messages to enrich location data. Human NERD stands for Human Named Entity Recognition with Deep learning and it applies deep learning and human in the loop to annotate data in specific domains where there are no predefined labelled datasets.

TASK 3.2: HOLISTIC TRAJECTORIES DATA MANAGEMENT (LEADER: UNIVE) (M6-M60).

According to the GA Annex 1 Part B the objective of the Task 3.2 is "to provide the requirements for storing holistic trajectories and processing efficiently complex queries over them. The goal is designing and implementing a unifying data access layer dealing with the inherently heterogeneous nature of holistic trajectories, a building block of any analytical process."

This task activity has been carried out during 10 secondments reported in Table 1: #25, #22, #8, #106, #11, #38, #39, #104, #109, #16 executed by secondees Marta Simeoni, Alessandra Raffaetà, Chiara Renso, Beatrice Rapisarda, Marios Vontas, Nikolaos Koutroumanis for a total of 9,93 PM. The majority of these secondments have been already described in D3.1 but for the sake of completeness they are all reported below.

During Secondment #25, Marta Simeoni (UNIVE), seconded at DAL, started a collaboration with Prof. Matwin and his group to work together on a dataset containing fishing catches data of the North Adriatic Sea. These data were provided by suitably querying the data warehouse developed and maintained at UNIVE. The main

idea was to develop a predictive model for the Catch Per Unit Effort, an indicator of the fishing resources exploitation useful for fishery management, by applying standard or deep learning techniques. The work brought to the creation of a set of holistic trajectories obtained by merging three data sources: trajectories from fishing vessels, the corresponding fish catch reports (i.e., the quantity and type of fish caught), and relevant environmental data. This research has been published at the First International Workshop MASTER 2019 [5]. Then the collaboration continued and resulted into two further publications [6, 8].

During Secondment #22, Alessandra Raffaetà (UNIVE), seconded at UFC, coped with the problem of the reconstruction of trajectories starting from very sparse datasets. In fact, at UFC, a dataset consisting of multiple readings of fixed sensors installed all over Ceará state is available. This has resulted into a hard task because the sensors were sparse: they covered well only few areas and sometimes they did not capture the passage of a vehicle because they were temporarily not working or blocked by other objects. By using a simple linear interpolation, connecting consecutive readings for the same vehicle resulted into puzzled behaviours of the objects. As a consequence, the analysis was restricted to vehicles showing *recurrent* behaviours, i.e., vehicles that exhibit a similar behaviour in several days of the week. In this case it is crucial to take into consideration multiple periodicities: weekdays, weekend, holidays and so on. The ultimate goal of this analysis is to predict the next relevant position for a vehicle by using the information stored in the dataset.

During Secondment #8, Chiara Renso (CNR), seconded at UFCS, finalized a conceptual and logical model for multiple aspect trajectories called MASTER. Together with Prof. Bogorny and Prof. Ronaldo de Mello, they defined the concept of multiple aspect trajectory and they coped with storage issues of these trajectories. In fact, they provided the conversion of the conceptual data model into a logical schema in the Resource Description Framework (RDF) standard to be adherent to the *Semantic Web Linked Open Data* standards. Also they discussed the usage of a triplestore based on NoSQL databases for maintaining RDF data. This work resulted in the publication [1].

During Secondment #11, #104 and #109, Beatrice Rapisarda (CNR), seconded at UFSC, at UFC, PUC, respectively, designed and started the implementation of a data access infrastructure to give access to the project Consortium to the many methods and datasets available at UFSC, UFC and PUC. Together with the researchers of the project partners she prepared a list with the available resources and they discussed which was the best design solution for them and for the needs of the MASTER project.

During secondment #106, Chiara Renso (CNR), seconded at UFSC, worked in collaboration with Beatrice Rapisarda (CNR) and Prof. Vania Bogorny (UFSC) for defining the data access infrastructure for the UFSC resources that could support the construction of holistic trajectories from heterogeneous data sources. She also continued the collaboration with Prof. Mello for extending the MASTER conceptual model with analytical dependencies.

During Secondment #38, Marios Vontas (UPRC), seconded at PUC, studied the literature for trajectory indexing. He found interesting the survey by Mahmood et al. "Ahmed R. Mahmood, Sri Punni, Walid G. Aref: Spatio-temporal access methods: a survey (2010 - 2017). GeoInformatica 23(1): 1-36 (2019)". The survey presents an overview and a broad classification of the spatio-temporal access methods into the following categories: (1) indexes for historical spatio-temporal data, (2) indexes for current and recent spatio-temporal data, (3) indexes for future spatio-temporal data, (4) indexes for past, present, and future spatio-temporal data, (5) indexes for spatio-temporal data with associated textual data, and (6) parallel and distributed spatio-temporal systems and

indexes. Then Marios discussed with Prof. Casanova and his research group how the methods presented in the survey could be relevant for the MASTER project.

During Secondment #39, Nikolaos Koutroumanis (UPRC), seconded at PUC, carried out research about the performance of spatio-temporal queries over MongoDB. The database (a NoSQL database) was deployed on a distributed environment, storing GPS traces from trajectories as Documents. Two indexing methods were adopted on each node: the first uses the (built-in) compound index that MongoDB offers, including both the spatial and temporal information. The second one maps the spatio-temporal data into 1D values by exploiting the Hilbert space filling curve. When the first indexing method was adopted, range partitioning was applied on the date field so as to distribute the documents among the nodes. In the second indexing method, range partitioning was applied on the Hilbert key field. The execution time results of the queries showed that only some spatio-temporal queries which were selective in terms of both space and time, benefited from the Hilbert approach. Also, the number of the using bits seemed to affect the performance of queries.

During Secondment #16, Chiara Renso (CNR), seconded at PUC, presented to Prof. Casanova and his students the current state of the MASTER project concerning the data integration of semantic aspects to movement data. In particular she illustrated the MAT-builder tool, a system designed to support users during the whole semantic enrichment process and to allow for the use of a variety of external data sources. Moreover, she introduced the graphDB extension of the tool to be able to integrate Linked Open Data. The idea is to be able to adopt the MAT builder software and LOD framework for the PUC datasets and needs.

3. CONCLUSIONS

In summary, the main contributions related to Tasks T3.1 and T3.2 are:

- A semi-supervised approach to partition trajectories into meaningful segments. This is a fundamental step to enrich trajectories with significant annotations (Secondment #78).
- Techniques to extract multi-modal aspects, i.e., different kinds of semantic information, from private datasets and knowledge bases, user-generated content and Linked Open Data, to be used as annotations in order to build holistic trajectories (Secondments #12, #7)
- A visual-analytics based platform to assist the user in the trajectory annotation process (Secondments #80, #1, #16)
- Definition of a conceptual and logical model for multiple aspect trajectories (Secondments #8)
- Investigation of solutions to reconstruct and store holistic trajectories (Secondments #22, #25)
- Design and creation of a data access infrastructure for holistic trajectories (Secondments #11, #106, #104, #109)
- Investigation and preliminary proposals of indexing methods to improve the processing of complex queries on holistic trajectories (Secondments #38, #39)

In addition, during the secondment research activities, the ESRs have performed training activities (e.g attending seminars and courses) as specified in the WP3 objectives.

4. PUBLICATIONS

[1] A. Soares, J. Rose, M. Etemad, C. Renso, S. Matwin. VISTA: A visual analytics platform for semantic annotation of trajectories. Demo paper at EDBT 2019, Lisbon, Portugal. This is publication N. 17 in SyGMA as workshop proceedings. Link to repository: https://zenodo.org/record/2658086#.XljxqS3MyuU

[2] C. Sardianos, I. Varlamis, G. Bouras. Extracting user habits from Google maps history logs. In Proc. Of ASONAM 2018, Barcelona, Spain. This is publication N. 26 in SyGMA as conference proceedings. Link to repository: https://zenodo.org/record/2649784#.XlO4Cy2ZNUM

[3] A. Soares, V. C. Times, C. Renso, S. Matwin, L. A. F. Cabral. A semi-supervised approach for the semantic segmentation of trajectories. Proc. of MDM 2018, Aalborg, Denmark. This is publication N. 2 in SyGMA as Conference proceedings. Link to repository: https://zenodo.org/record/2657845#.XMrrOC-B1dA

[4] R. dos Santos Mello, V. Bogorny, L. O. Alvares, L. H. Z. Santana, C. A. Ferrero, A. A. Frozza, G. A. Schreiner, C. Renso. MASTER: A Multiple Aspect View on Trajectory. Transactions in GIS 23(4) *805-822 (2019)*. This is publication N. 19 in SyGMA, article in journal. Link to Repository: https://zenodo.org/record/3685620#.XlOtoy2ZNUM

[5] Pedram Adibi, Fabio Pranovi, Alessandra Raffaetà, Elisabetta Russo, Claudio Silvestri, Marta Simeoni, Amílcar Soares, Stan Matwin. Predicting Fishing Effort and Catch Using Semantic Trajectories and Machine Learning. Proc. of MASTER 2019, Würzburg, Germany. This is publication N. 20 in SyGMA chapter in a book (workshop proceedings). Link to repository https://zenodo.org/record/3678159#.XlO41i2ZNUM

[6] Giulia Rovinelli, Stan Matwin, Fabio Pranovi, Elisabetta Russo, Claudio Silvestri, Marta Simeoni, Alessandra Raffaetà. Multiple aspect trajectories: a case study on fishing vessels in the Northern Adriatic sea. Proc. of the BMDA Workshop 2021 in conjunction with EDBT 2021, Nicosia, Cyprus. This is n. 38 in SYGMA.

[7] Chiara Pugliese; Francesco Lettich; Chiara Renso; Fabio Pinelli. MAT-Builder: a System to Build Semantically Enriched Trajectories. Proc. of the 23rd International Conference on Mobile Data Management (MDM 2022). Paphos, Cyprus. This is n. 39 in SyGMA.

[8] Bruno Brandoli, Alessandra Raffaetà, Marta Simeoni, Pedram Adibi, Fateha Khanam Bappee, Fabio Pranovi, Giulia Rovinelli, Elisabetta Russo, Claudio Silvestri, Amilcar Soares and Stan Matwin. From multiple aspect trajectories to predictive analysis: a case study on fishing vessels in the Northern Adriatic sea. Geoinformatica 26(4): 551-579 (2022). This is n. 40 in SyGMA.