

# MASTER

Multiple ASpects TrajEctoRy  
management and analysis

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# Editorial

Welcome to the 7<sup>th</sup> issue of the MASTER newsletter!

With the easing of COVID related restrictions we can finally travel to our hosting institutions! During the last 8 months we executed 15 secondments to our partners that include Thira, Federal University of Ceara', Pontifical University of Rio de Janeiro, Dalhousie and CNR. In this newsletter we briefly report about the activities carried out during these secondments.

We also report about two articles that partners published during the period, one of them, from our partners UFSC and CNR, winning a demo award.

We also restarted our events and we are so proud to report about the Second MASTER workshop held in Venice hosted by our colleague Dr. Alessandra Raffaeta' of University Ca' Foscari! The event entitled "MASTER meets Mobility Industries" has been an amazing opportunity to meet the non academic world and strengthen our collaborations with them!

We also held our First Summer school called "Data Science for Mobility" in the stunning Santorini island. The event was originally planned in April 20220 and then postponed due to the pandemic.

The DSM summer school has been a n exceptional success since the whole event has been greatly appreciated by our participants. The event has been a unique opportunity to train young scientists in the mobility topic.

In conjunction with the summer school, we also held a mid term meeting among the MASTER european partners, with the objective of discussing the next secondments.

You can download this and previous issues of the newsletter from the MASTER web site:

<http://www.master-project-h2020.eu>

Stay tuned and happy reading!

*Chiara Renso, MASTER Project Coordinator*

# MAT-Builder: a System to Build Semantically Enriched Trajectories

Chiara Pugliese, ISTI-CNR, Pisa and University of Pisa, Italy

## INTRODUCTION AND RELATED WORKS

The notion of multiple aspect trajectory (MAT) has been recently introduced in the literature [1] to represent movement data (i.e., a moving object trajectory) that is heavily semantically enriched. These trajectories can be seen as positioning data augmented with different dimensions, or aspects, representing various types of semantic information that are relevant or contextual to the

(1) the parts of the trajectory to be enriched,  
 (2) the various types and sources of semantic data to be used for the enrichment, and  
 (3) the most suitable approaches to properly associate spatio-temporal data with semantic information.

For what concerns existing solutions, there are several libraries [2,3], dashboards [4,5], and ontology-based approaches [6] that are able to process

pose MAT-Builder, an interactive system that supports practitioners during the whole trajectory semantic enrichment process and that enables users to generate datasets of multiple aspect trajectories. The MAT-Builder system is written in Python and is made up of a user interface (UI) (Fig. 2) and the modular backend.

The backend is the core of our system, and it is organized by module, where each module corresponds to a step of the semantic enrichment process.

The pre-processing module (blue block in Fig. 1) takes in input a set of raw trajectories and filters out noisy or unusable data to facilitate the activities of the other modules

The segmentation module (green block in Fig. 1) takes in input a set of pre-processed trajectories and partitions every trajectory into sub-trajectories (or segments) following the stop and move criterion.

The segment enrichment module (yellow block in Fig. 1) takes the output of the previous module and identifies the different segments to enrich, the aspects to consider, the datasets to be used to enrich the segments with different aspects, and the enrichment criteria.

The stop enrichment sub-module enriches the stop segments with the regularity aspect, i.e., it distinguishes between systematic and occasional stops. Stops that fall within the same area more than a given number of times are considered to belong to the same systematic stop. Systematic stops are enriched with the activity performed by the moving object

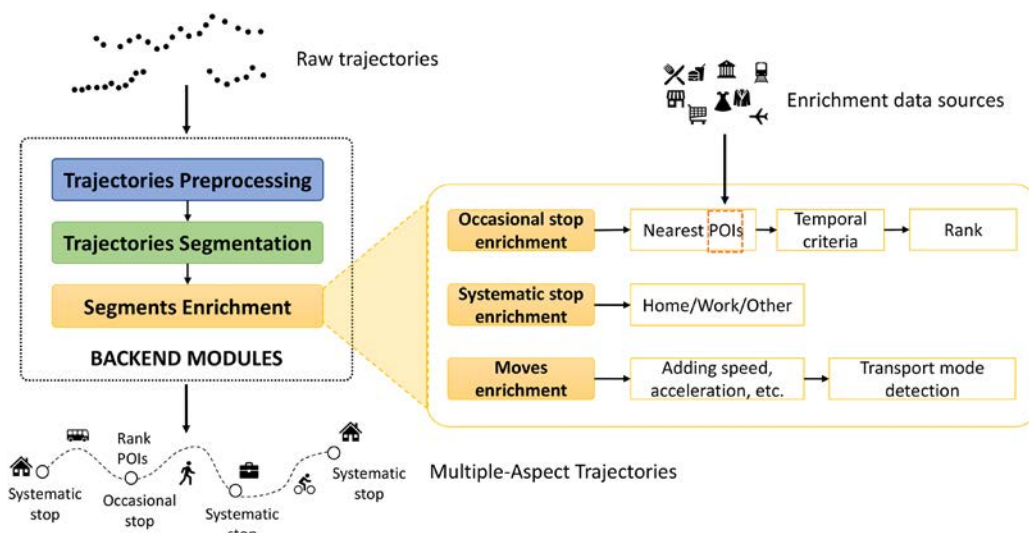


Figure 1. MAT-Builder backend.

data they are associated with. A few examples of aspects can be stops, moves, weather, POIs, transportation means, activities performed, social media posts, and so on. The aspects associated with a trajectory may be large in number, heterogeneous, and structurally complex. Moreover, we observe a general lack of tools that can support users during the complex process of creating these datasets. Generally speaking, this process requires to identify

and extract insights from trajectory data, while others propose trajectory enrichment with specific data sources (e.g., [7]). Unfortunately, these solutions either do not perform semantic enrichment or, when they do, they are limited to a fixed number of aspects, are not extensible, or they do not support the use of external data sources.

## OUR SYSTEM

To overcome these limitations, we pro-

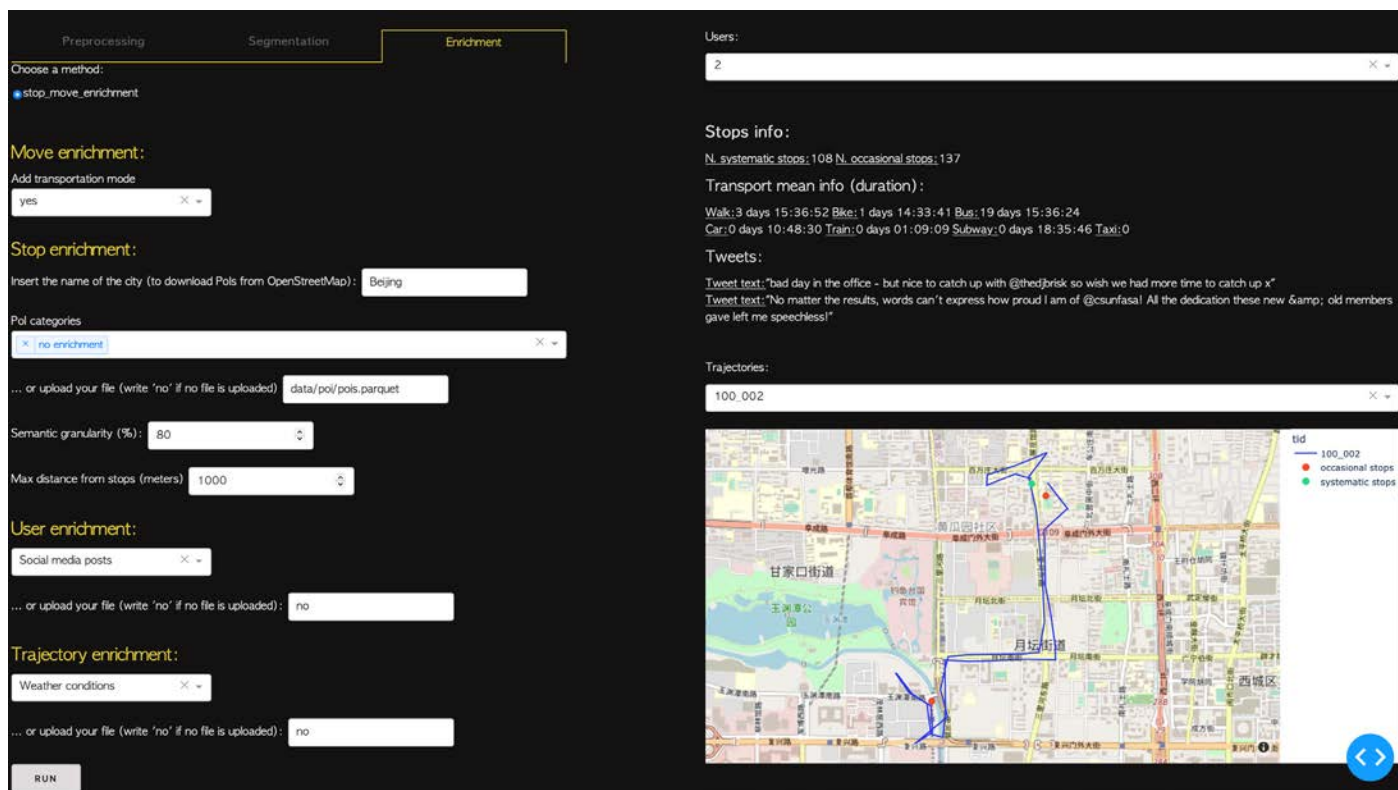


Figure 1. MAT-Builder UI

(e.g., home, work and other) Conversely, stops that do not satisfy this criterion fall within the occasional category. Occasional stops are enriched with the k-nearest Points of Interest.

The move enrichment sub-module focuses on enriching the move segments. In the present version, the module enriches with two aspects: quantitative numerical measures and transportation means (predicted by a random forest classifier trained on the Geolife dataset).

The trajectory enrichment sub-module enriches the entire trajectory with the weather conditions.

Finally, the user enrichment sub-module enriches the users with synthetic social media posts.

## CONCLUSIONS

MAT-Builder is a system that supports users in creating multiple aspect trajectory datasets starting from raw trajectories and external data sources. The semantic enrichment process offered by MAT-Builder includes trajectory preprocessing, trajectory segmentation, and segment enrichment, allowing users

to customize the entire process and to choose which part(s) of trajectories to be enriched.

### For more details:

Pugliese, C., Lettich, F., Renso, C., & Pinelli, F. (2022, June). Mat-builder: a system to build semantically enriched trajectories. In 2022 23rd IEEE International Conference on Mobile Data Management (MDM) (pp. 274-277). IEEE.

# MATB

Multiple Aspects Trajectory Builder

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D. Rodriguez. Using vodafone mobile phone network data to provide insights into citizens mobility in italy during the coronavirus outbreak. *Data & Policy*, 3:e22, 2021.

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A framework for annotating semantic trajectories based on episodes.

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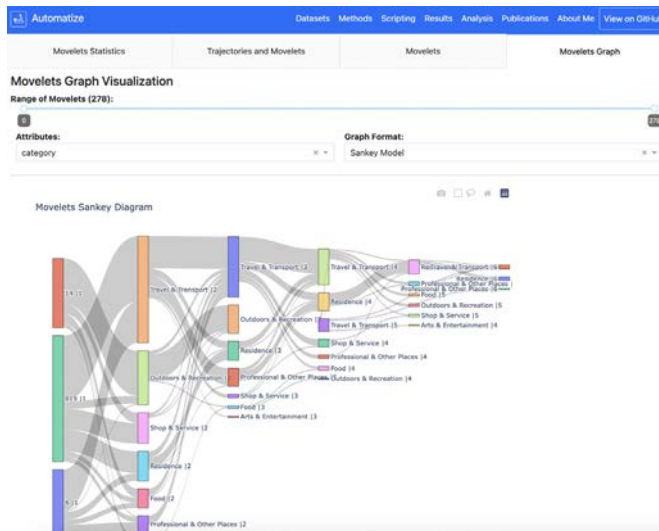
[7] Nikolaos Koutroumanis, Georgios M. Santipantakis, Apostolos Glenis, Christos Doukeridis, and George A. Vouros. Scalable enrichment of mobility data with weather information. *GeoInformatica*, 25(2):291–309, 2021.



# AutoMATise

## A solution to make mobility data classification and visualization accessible and reusable.

Tarlis Tortelli Portela, University of Santa Catarina, Brazil, University of Pisa and ISTI-CNR, Pisa, Italy



such high dimensional data.

**In a nutshell, AutoMATise's objective** is to foster both data visualization and a complete configuration of classification experimental settings. The architecture of AutoMATise is shown in Figure XX, and it is composed of five main modules: Data Pre-processing, Scripting, Analysis, Results, and Visualization Tools.

23rd IEEE International Conference on Mobile Data Management (MDM), being awarded with Best Demo Runner-Up.

### WHAT'S NEXT FOR AUTOMATIZE ?

There are endless possibilities to extend the platform with new classification methods, other preprocessing features, and other mining tasks (clustering, prediction, etc.). Collaboration is the key. It is an open source platform where any developer or researcher can contribute, extend and develop new features. But, more importantly, it can be made available for everyone.

#### For more details:

"AutoMATise: Multiple Aspect Trajectory Data Mining Tool Library," 2022 23rd IEEE International Conference on Mobile Data Management (MDM), 2022, pp. 282-285, doi: 10.1109/MDM55031.2022.00060.

*This paper is a joint work between partners Federal University of Santa Catarina (Brazil) and National Research Council (Italy)*

The software is available at <https://github.com/tportela/automatize>

### WELCOME AUTOMATIZE.

The present application offers a tool to support the user in the data mining task of classification for the mobility data. Specifically, for multiple aspect trajectories (MAT), that are a complex type of multidimensional and sequential data. The challenge for classification of such trajectory data lies in extracting and visualizing the movelets, the parts of the trajectory that better discriminate a class. This platform meets the challenge by offering tools to support the mining tasks including: preprocessing the data, environment generation for experimental purposes, classification tools, results aggregation, synthetic data generation and mobility data visualization tools.

The **movelet-based trajectory** data mining faces challenges for visualizing the high dimensional data, and the movelets associated with the trajectory data. Moreover, providing the user with a unique platform for accessing the different tools available for movelet extraction and trajectory classification is another fundamental motivation to the platform creation, thus, to make understandable the patterns extracted from

**As its name suggests**, it integrates into a unique platform for the automatization of the classification task of mobility data. It assembles fragmented approaches available for multiple aspects trajectories and in general for multidimensional sequence classification into a unique web-based and python library system. It has a friendly web-interface that allows the user to interact with most of the functions from the Python library.

**On top of that, it is an open source** platform that was designed to be easily extended for other types of data and feature visualizations. Since multiple aspect trajectories is a model general enough to represent other domains, other types of multiple dimensional sequential data can be represented, such as the multivariate time series, event logs or genetic sequences.

The **AutoMATise demo** was presented in the 2022



AutoMATise best demo runner-up award

# MASTER meets Mobility Industry

## Second MASTER workshop in Venice, Italy

On May 13th 2022 we held the Second MASTER workshop. The event has been organised by our partner Alessandra Raffaetà of the Ca' Foscari University of Venice, in the room Aula Magna Silvio Trentin at Ca' Dolfin, in the historical centre of Venice.

The title of the workshop was "MASTER meets Mobility Industries" where the objective was to find links with the industrial world of mobility.

Companies *ACTV Venice*, *BusForFun* and *Mindicity* kindly agreed to give a presentation, introduce their companies, the data they manage, and the analysis problems they are facing.

In addition, we invited two European projects related to mobility data, *MOBIDATALAB* (Thierry Chevalier from AKKA, France) and *VesselAI* (Spiros Mouzakitis from NTUA, Greece).

MASTER Partners – Chiara Renso from CNR, Alessandra Raffaetà and Giulia Rovinelli from UNIVE, Konstantinos Tserpes from HUA, Nikos Pelekis from UPRC, Karine Zeitouni from UVSQ – presented their latest results and the research activities in the project.

The Independent Ethical Advisor, Prof. Bettina Berendt, closed the meeting presenting the experience of the Dagstuhl Seminar and the ethical challenges in this domain.





# Data Science for Mobility Summer School

**During the week** from October 3rd to October 7th 2022 we held the First International School on Data Science for Mobility, supported by MASTER.

**The program of the school** included two keynote speakers, Prof. Goce Trajceski and Prof. George Vouros, the three mini courses on Big Data Analytics, Human Mobility Analysis and Deep Learning for mobility.

A panel on emerging issues of mobility data concluded the scientific activities.

**We also organised three social events:** the welcome cocktail, the sunset at Oia and the wine tasting experience.

**The full program** is available at the school web site: <http://master-school.isti.cnr.it>

**We counted 49 participants** coming from 10 countries in Europe and outside, many of them being PhD students.

**Participants enjoyed** an interactive and informal atmosphere, having the op-

portunity to increase their skills while strengthening their network connections with colleagues and experts in the field.

**At the end of the school**, we submitted a survey to the participants to collect, anonymously, their opinions on various aspects concerning the school. As we learned from the anonymous survey, the school was very much appreciated, both for the programme, which was rich and interesting, and for the general organisation.





# Survey to participants

## DSM SUMMER SCHOOL EXPERIENCE IN THREE WORDS

Nice Sharing Experience

Amazing, useful, funny

Useful, interesting, great social interactions

Sea, Sun, Science

A super exciting experience!

Process mobile data for various purposes

Interesting, innovative, enjoyable

ING Comprehensive mobility\_data course

Experience, Knowledge, Hands-on

Insightful, rewarding, unforgettable

## THE MOST APRECIATED ASPECT

Organization, keynotes, tutorials

The strong interaction among the participants

Social program, hands-on activities (scikit-mobility and deep learning for mobility data)

The possibility of talking to other passionate and inspiring Mobility students

The kindness and the availability of the organizers and the modesty of the teachers

The high quality of the scientific program

The balance between work and social activities

The mini-courses were very helpful and the keynote talks were interesting

The location, the meals, and the hands-on courses, and the social program

I liked meeting new people in my area of expertise

## COMMENTS

The DSM school has offered a unique opportunity of high-quality training in the topic of mobility data science for students and young researchers. It was also a place for networking, both through the classes and the hands-on sessions (organised by small groups) and the social program. The school was attractive (given the participation) and, in my view, very successful.

Congratulations to all organizers. I want to thank the opportunity to have attended the DSM. It was a really groundbreaking event in my formation as a researcher and data scientist.







PAST EVENTS





# Secondments

## Experiences and results



*Marta Simeoni and Alessandra Raffaetà (UniVE) at Dalhousie University, Halifax, Canada*

**Tarlis Tortelli Portela from UFSC** visited CNR in January 2022.

Tarlis' secondment has been focussed on the efficient extraction of movelets for multiple aspects trajectories. Movelets are those parts of a trajectory that better discriminate classes in trajectory classification tasks and it is a very time-consuming task especially for trajectories with several semantic dimensions. Specifically during his secondment developed a tool for interpreting and visualising mined patterns in holistic trajectories that won a Best Demo Runner Up at the Mobile Data Management Conference, 2022.

**Zaineb Chelly Dagdia from UVSQ** have been seconded to Thira municipality in Santorini island in May 2022. They discussed several research perspectives like how to perform optimization of tourism routes. Examples of the constraints that can be covered are the location information of some attractions, and the transportation costs between some attractions. Zaineb highlights how these kinds of problems can be solved by the

application of Evolutionary Algorithms (EA), such as genetic algorithms, evolution strategy, etc.

**Francesco Lettich from CNR** visited UFC in March 2022. His secondment focussed on external sensor trajectories (ESTs), i.e. sparse trajectories collected through the observations of a sensor network deployed within some urban area. In particular, with the ESTs the hosting unit has in the past dedicated a substantial amount of research efforts to tackle the next location prediction problem, which has been then addressed with machine learning and deep learning techniques. The objective is therefore to collaborate to apply these techniques in the case of (sparse) multiple aspects trajectories.

**Antonios Makris from HUA** has been seconded to DAL in June 2022. Together with the Prof. Matwin's group, he investigated Unsupervised Learning of Visual Features by Contrasting Cluster Assignments and Deep Clustering for Unsupervised Learning of Visual Features.

**Beatrice Rapisarda and Chiara Renso from CNR and Karine Zeitouni and Mohammad Abboud from UVSQ** have been seconded to UFC in June/July 2022 to work with Prof. Jose Fernandes de Macedo (UFC) group. One of the topics from CNR is the design of the unifying access layer together to include their datasets and methods in the repository. Furthermore, they discussed with the Prof. Macedo lab in the context of sparse trajectories and location prediction, and in the generation of synthetic datasets.

**Alessandra Raffaetà' and Marta Simeoni from UNIVE** have been seconded to Dalhousie University in August 2022. During this secondment they worked together with Jay Kumar on the prediction of the fishing effort for the fishing vessels in the Northern and Central Adriatic Sea. The fishing effort is an essential indicator for monitoring the fishing pressure on an area of interest over time.

**Chiara Renso, Beatrice Rapisarda and Raffaele Perego from CNR and Andrea Marin from UNIVE** visited PUC during August 2022. During their secondments they held lessons at PUC about their current research activities getting in contact with several students. They also discussed with Prof. Casanova about their current activities and plans for future secondments.





# Next Event



Big Mobility Data Analytics

## BMDA 23

28<sup>TH</sup>-31<sup>ST</sup> MARCH, 2023  
IOANNINA, GREECE

MASTER partners are organizing the 5th International Workshop on Big Mobility Data Analytics (BMDA) co-located with EDBT/ICDT Conference, 28th March-31st March, 2023 Ioannina, Greece

<https://www.datastories.org/bmda23/>  
<http://edbticdt2023.cs.uoi.gr/?contents=workshops.html>

### IMPORTANT DATES

- Abstract Submission: December 21st, 2022 (11:59PM PDT)
- Paper Submission: December 28th, 2022 (11:59PM PDT)
  - Notification of Acceptance: February 1st 2023
  - Camera Ready Paper Due: February 18th 2023
- Workshop date: March 28th 2023

From spatial to spatio-temporal and, then, to mobility data. So, what's next? It is the rise of mobility-aware integrated Big Data analytics. The Big Mobility Data Analytics (BMDA) workshop, started in 2018 with EDBT Conference, aims at bringing together experts in the field from academia, industry and research labs to discuss the lessons they have learned over the years, to demonstrate what they have achieved so far, and to plan for the future of mobility.

In its 5th edition, the BMDA workshop will foster the exchange of new ideas on multidisciplinary real-world problems, discuss proposals about innovative solutions, and identify emerging opportunities for further research in the area of big mobility data analytics, such as deep learning on mobility data, edge computing, visual analytics. The workshop intends to bridge the gap between researchers and big mobility data stakeholders, including experts from critical domains, such as urban / maritime / aviation transportation, human complex networks.

We invite papers discussing novel research and ideas without substantial overlap with papers that have been published or submitted to a journal or a conference with proceedings. Submitted papers can be of two types:

- Regular Research Papers: these papers should report original research results or significant case studies. They should be 5000-8000 words (at most 8 pages) long.
- Demo Papers: these papers should showcase cutting-edge mobility data analytics software. They should be 2500-4000 words (at most 4 pages) long.

### ORGANIZATION AND SUPPORT

#### Workshop organizers:

- Christos Doulkeridis, University of Piraeus, Greece (cdoulk@unipi.gr) – primary contact
- Alessandra Raffaetà, Ca' Foscari University of Venice, Italy (raffaeta@unive.it)
- Esteban Zimányi, Université Libre de Bruxelles, Belgium (estebanzimanyi@gmail.com)

#### Supported by:

- MobiSpaces (New Data Spaces for Green Mobility, 2022-25)
- VesselAI (Enabling Maritime Digitalization by Extreme-scale Analytics, AI and Digital Twins, 2021-23)
- MASTER (Multiple Aspects Trajectory Management and Analysis, 2018-23)



# MID TERM MEETING IN VERSAILLES

**FEBRUARY 24TH 2023  
VERSAILLES, FRANCE**

We will hold our final mid term meeting in February hosted by prof. Karine Zeitouni in Versailles, France on February 24th 2023. The objective is to align our final secondments, the next deadline in terms of milestones and deliverables in preparation of the project final event!



*University of Versailles Saint-Quentin-en-Yvelines*





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