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# PROJECT PERIODIC REPORT

**Grant Agreement number:**

**Project acronym:**

**Project title:**

**Funding Scheme:**

**Date of latest version of Annex I against which the assessment will be made:**

**Periodic report:** 1st ☐ 2nd ☐ 3rd ☐ 4th ☐

**Period covered:** from to

**Name, title and organisation of the scientific representative of the project's coordinator[1]:**

**Tel:**

**Fax:**

**E-mail:**

**Project website[2] address:**

[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

## Declaration by the scientific representative of the project coordinator

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate) [3]:

  ☐ has fully achieved its objectives and technical goals for the period;

  ☐ has achieved most of its objectives and technical goals for the period with relatively minor deviations.

  ☐ has failed to achieve critical objectives and/or is not at all on schedule.

- The public website, if applicable

  ☐ is up to date

  ☐ is not up to date

- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: ....................................................................

Date: ............/ ............/ ............

For most of the projects, the signature of this declaration could be done directly via the IT reporting tool through an adapted IT mechanism and in that case, no signed paper form needs to be sent

[3] If either of these boxes below is ticked, the report should reflect these and any remedial actions taken.

## 3.1 Publishable summary

**Summary**

Website: http://toposys.org

The goal of the TOPOSYS project is to build a theoretically sound foundation for the study of dynamic multi-scale complex systems using newly developed tools in applied and computational topology. Computational topology is a relatively new and rapidly developing field, which extends tools from algebraic topology to more computationally friendly forms. It also deals with extending the corresponding theory to situations, which are more applicable to scientific inquiry (such as defining a meaningful topology of a sampled metric spaces).

At their core, these tools are well-suited to the study of complex systems – they have a intrinsic local-to-global flavour, extracting and inferring qualitative global behaviour from local observations. The ability to go from local to global scales is crucial to develop the rigorous notions of multi-scale behaviour. Likewise, the qualitative, yet mathematically well-founded nature of the descriptions of systems abstract away the details which allows for a clearer analysis. For example, in the study of dynamical systems –we cannot describe the path a particular flow will take around a strange attractor in a chaotic system, we can often say meaningful things about the trajectory as an entirety, and its abstract properties.

The focus of the project is on techniques based on persistence, an inherently multi-scale approach. Rather than study a single scale or time slice, persistence studies is how a space changes either over different scales or over time. Furthermore, the approach is algorithmic with a strong emphasis on computable invariants – especially for large scale and high dimensional data. With the algorithmic approach, we are able to consider inverse problems, such as reconstructing dynamical behaviours from discrete point samples.

**Objectives:** The objectives of this project align along three main directions:

1. **Persistence of maps –** The first goal is to move to a more explicitly *functorial* approach. Rather than concentrate on the objects (e.g. sampled spaces), we concentrate on the maps between these objects. For example, a dynamic system can be viewed as a map from a space to itself, where each application of the map iterates the system forward. To understand the dynamics of a system, we must understand the properties of this map. The first objective within this goal is to define a theory of persistence on the space of maps, which is amenable to sampled data. The second objective is to extract more refined information in cases where this is possible. For example, a natural model recurrent dynamics is the circle, which can be parameterized by cohomological techniques. Finally, in complex systems, we often have vastly different measurements, which must be combined coherently which we examine as the problem of exploring different types of hierarchies of maps.

2. **Statistics and topology –** Statistics forms the basis of data analysis, but it has proven difficult to apply it in topological settings. One of our goals is to help bridge the gap between statistics and topology – using the strengths of both. The first objective is to gain a better understanding of the statistics of topological noise. Topological results give a bound on the magnitude of the noise but relies on quantites which cannot be measured or estimated. More advanced probabilistic techniques will allow more general noise models to be considered and gaining a more complete understanding the behavior of the noise in our techniques. Furthermore, the exploration of the consequences of doing statistics on the output of persistence theory is still relatively unexplored. The existing results point to the possibility of rigorous model selection – which is our second objective. Our final objective is to combine topology and statistics to better understand smoothing processes as this is a natural component in many multi-scale notions.

3. **Categorical foundations -** Category theory is a powerful language, which is already ubiquitous in mathematics. Phrasing existing techniques within a categorical setting often reveals useful abstractions and connections. Our goal is to explore categories as a fundamental abstraction tool for topological and algebraic approaches to systems. The first objective is to place persistence in the setting of a topos of sheaves, which if successful will unify various aspects of the foundations of persistence theory. Our second objective is to examine the use of sheaves in a statistical or machine learning context. Sheaf theory is a formal machinery which allows for general transitions between local and global properties. This has gained intense interest in the applied topology community over the last few years. Finally, we look at generalizations of persistence so that they may be more directly relevant to dynamic systems.

4. **Validation and Applications –** to validate the efficacy of our approach, the objective is to validate with applications from robotics and social media. The former is not a traditional "complex systems," however serves as an important stepping stone towards more complex systems. Social media refers primarily to textual linked data, which may come from Twitter, Wikipedia, or other sources. Note that the methods will not be tied to these datasets and as opportunities arise, other datasets will be considered.

The project combines four areas: category theory, statistics, and dynamical systems with computational topology as the joint platform for the three other component in order to work towards a mathematically rigorous description of the dynamics of a system from a local to a global scale. In this framework, multi-scale features have a natural place, and the focus on computation and algorithmics means we can easily verify and validate our theory.

**Major Achievements**

In the second year there has been significant progress on several fronts – especially on the topoidal basis of persistence. Building on the Heyting algebra developed in the first year, we have developed the variable-time set theory and have nearly completed the construction for computing homology over this family of set theories. We have also developed an algebraic-topological framework for semi-supervised learning as well as a combinatorial/categorical interpretation of interleaved persistence modules.

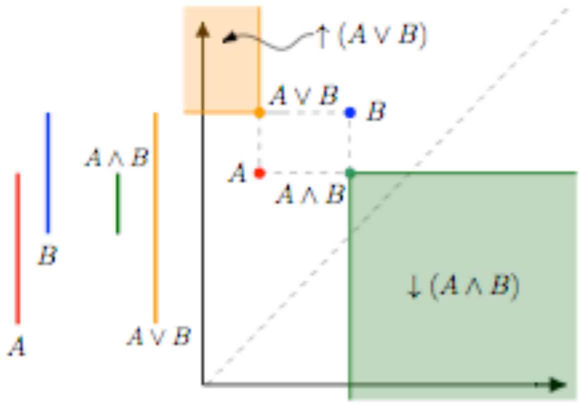


Figure 1 Heyting algebra for intervals

We have made progress on the topology of noise (WP2). In particular, we have given central limit theorems for Betti numbers and are currently expanding the work to cover persistent Betti numbers. Furthermore, we have developed kernels over persistence diagrams, which allow the incorporation of persistence diagrams into standard machine learning algorithms. Furthermore we have investigated the simplification of two dimensional vector fields (currently being extended to three dimensions). There have also been advances in using the Euler characteristic curve for threshold selection. Finally we have developed a pipeline for testing the topology of noise coming from different distributions.

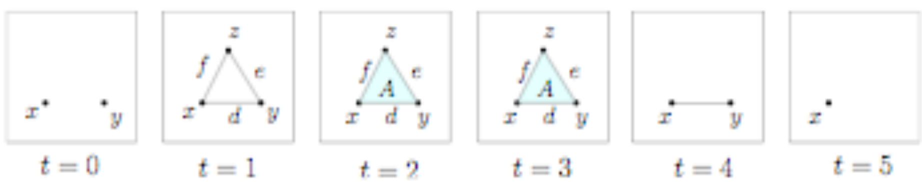


Figure 2 Toy example of variable-time set theory (in this case equivalent to zig-zag persistence)

We have further developed application in robotics – we have also demonstrated the use of relative homology in the identifying homotopic paths for planning. Experiments on a number of datasets including: Wikipedia, Twitter, and ArXiV among others, have demonstrated shortcomings in some of the algorithms, which are currently being developed. However, we have developed a complete prototype of a pipeline for the persistence of a self-map as well as parameterizing recurrent motion (where the time slices are given as points in some metric spaces). In addition to the social media data and robotics data, we have also investigated topological approaches to tracking epidemics (with data from InfluenzaNet) and genetics data, with preliminary reports presented at workshops.

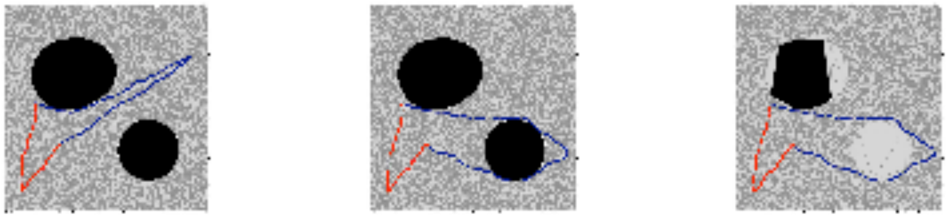

**Figure 3 Homotopically different paths for configuration spaces, which can be detected via relative homology.**

We have also further developed, the self-map application, with work on the algorithm as mentioned above as well as computation on determining the eigenvalues of a self-map. Related to this work, although having a wider implication across the project are new results on the equivalence of Delaunay, Čech and Wrap complexes across all dimensions through simple homotopies. This work has the promise of helping reduce the size of the complexes we need to consider, vastly speeding up our algorithm.

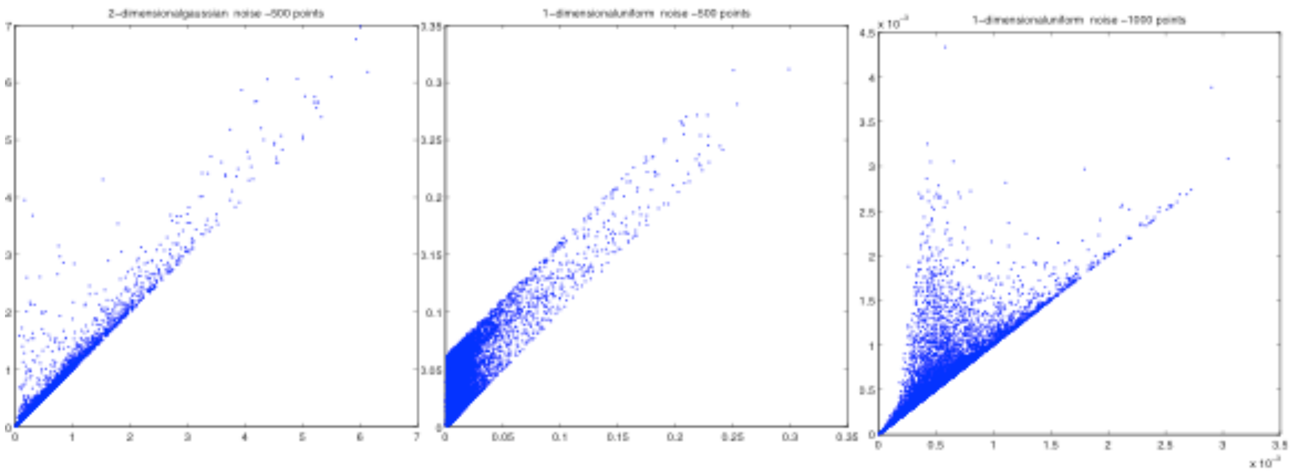

**Figure 4 Persistence diagrams of different models of noise**

Finally, in terms of dissemination, we had a greater presence at ECCS 2014, along with numerous talks (invited and contributed) and seminars – many of which where within the context of the special IMA thematic year.

**Expected results and impact**

The expected results of the project are the far reaching generalizations of persistence and applied topology in terms of theory, implementations and applications. We expect that by the end of the project, the tools will be available to be able to process large datasets form complex systems. This will offer a different and orthogonal perspective to the methods, which are currently used. In particular, there will be implementations available to compute the persistence of maps as well as find recurrence for general dynamic structures (such as dynamic graphs which are common in the social media context). We have constructed generalizations in several directions including the persistence of self-maps (with persistence of pairs of maps and triples of spaces currently under investigation).

While many of the techniques we use are highly technical, the results of computation are often quite simple to understand: for example, segmenting different motions has a clear interpretation as do the grasping points. This makes a wider impact more likely. Some of the results may be more counterintuitive, such as the presence of crackle and a degree two map. However, the results allow us to qualitatively describe behaviour in terms of a small amount of information (e.g. a form of persistence diagram).

## *3.2 Core of the report for the period: Project objectives, work progress and achievements, project management*

### 3.2.1 Project objectives for the period

The objectives for TOPOSYS for this period revolve around the four research work packages, which although somewhat independent interact in fundamental ways. The most obvious of these interactions is for WP4, which utilizes the results of the other work packages on applications as well as for verification. However, other interactions are important as well. In particular, generalizations developed in WP3 are crucial for progress in WP1. With the progress in the WP3 this year we will make rapid progress on certain parts of WP1.
WP2 is perhaps the most independent but also crucial for a proper analysis of data as well as offering solutions to challenges which the other approaches cannot deal with. In particular statistical and algebraic approaches have different strengths and weaknesses.

As such the objectives in the second year were more, illustrated through the work in WP3 as well as the Čech-Delauanay construction which has been used in the other work packages.. We now highlight the individual objectives for this year in the different work packages as well as highlight the expected future interactions.

### WP1 Persistence of Maps

**Main Objectives**

The ultimate objective of WP1 is to look at relationships between spaces in the form of maps, through the lens of persistence.

**Task 1 – Jordan forms for homology –** The objective in the second year was to deliver prototype code for computing the persistence of a self-map. Furthermore, we sought to develop

**Task 2 – Cohomology of recurrent systems -** The objective in the second year was the delivery of preliminary code in Month 18. A secondary objective was to begin experimentation using the developed technniques.

**Task 3 – Hierarchies of maps** – This objective of this task in the second year was to begin performing computation on indecomposables using the progress in the first year as well as advances from WP3.

**Task 4 – Unified theory –** In the second year, the task was to begin looking for commonalities in the approaches we took in the various other tasks.

## WP2 Multiscale Statistics

### Main Objectives

The ultimate objective of WP2 is to examine and develop the relationship between statistics and topology.

**Task 1 – Topological noise –** The objective for this task was to further gain an insight into the structure of noise, which occurs in topological constructions coming from random processes. The ultimate goal is to understand the behaviour of bars as well as report on initial experimentation on noise processes.

**Task 2 – Bayesian persistence –** The goal in the second year of this task is to establish some possible approaches for help model selection problems as well as investigation of other topological invariants( other than homology) for capturing the topological structure over multiple scales (such as the Euler characteristic curve). Furthermore, how topological invariants could be used in machine learning algorithms

**Task 3 – The effects of smoothing –** The objectives in the second year were to develop ideas on for understanding smoothing.

## WP3 Categorical Systems

### Main Objectives

**Task 1 - Placing persistence into a categorical setting –** The goal of this task is to place persistence into a topos of sheaves. In the first year goal was to establish an underlying Heyting algebra upon which to develop a topos. Once this is completed, further investigation into definition of sheaves on top of this structure can begin.

**Task 2 - Statistical/machine learning sheaves -** The goal of this task was to better understand the machinery of sheaves and identify possible types of problems, which would be amenable to this type of framework. In addition but just as important was to gain some understanding of how computation could be done with sheaf-like structures to find objects such as global sections.

**Task 3 - Categorical dynamical systems –** the goal of this task is within the context of other work packages. More precisely, to understand generalizations of persistence in order to make the analysis required in the other work packages feasible. As such, this work package's goals of understanding and formalizing a categorical setting for persistence specifically tailored to dynamic systems will be concentrated in the latter part of the project, when a better understanding of the requirements is available.

## WP4 Validation and Applications

**Main Objectives**

The objective of WP4 is to provide datasets, application and verification for the techniques and approaches developed in the other work packages.

**Task 1 – Robotics and configuration spaces –** the objective was to look at applications within robotics in order to understand how topological tools may be used to either characterize behaviour or help with a more global understanding of a task or system. This serves as a stepping stone towards more complex systems where exploratory analysis will be required. In this instance, there is clearer test as to the results of the method.

**Task 2 – Social Media –** The objective in the second year was to continue to collect and prepare social media data, or more generally, linked textual data as well as interaction data of complex systems in order to facilitate experimentation in the following period.

## WP5 Dissemination, Collaboration, and Exploitation

**Main Objectives**

The main objective of this work package is to disseminate the results of the project as well as help coordinate community building the joint collaborative task and finally deal with exploitation.

**Task 1 – Dissemination & community building** - In terms of dissemination**,** the goal was to disseminate the results to the applied topology community as well as reach out to other potentially interested communities. In particular, having a presence at ECCS will increase the impact in the complex systems community. A further objective was to introduce applied topology to other applied fields such as machine learning.

**Task 2 – Joint Collaborative Task –** the objective of the joint collaborative task in the first year was to establish cooperation with TOPDRIM and SOPHOCLES projects within the DYM-CS unit. These are the projects with the lowest barriers to cooperation. The goal was to set up more concrete collaborations (scientific papers, sharing of data, etc.) in the upcoming periods.

**Task 3 – Exploitation –** the objective in the second year was to see what developments could potentially be exploited in an industrial or commercial setting as well as develop the code into workable demonstrations.

Please provide an overview of the project objectives for the reporting period in question, as included in Annex I to the Grant Agreement. These objectives are required so that this report is a stand-alone document.

Please include a summary of the recommendations from the previous reviews (if any) and indicate how these have been taken into account.

### 3.2.2 Work progress and achievements during the period

## WP1 Persistence of Maps

**Progress towards Objectives and Achievements**

Significant progress was made on all of the tasks.

**Task 1** – **Jordan forms for homology** has seen major progress in understanding the persistence of a self map. Given a space $X$, the work looks at a map $f: X \rightarrow X$. Just as in the classical case of linear dynamical systems, the space of endomorphisms is characterized by its Jordan form. The preliminary code has been delivered. There has been investigation and progress in computing all the eigenvalues for a self-map. Furthermore, a new connection between complexes promises better scalability when applied to the persistence of a self-map.

**Task 2** – **Cohomology of recurrent systems** has also seen significant progress. The code for computing the recurrence of as system in a metric space (and the corresponding paper on gaits). The paper on Poincare sections is nearing a state ready for submission. Finally, experimentation has begun on various datasets which have highlighted the importance of a choice of metrics (as well as the insufficiency of many widely used metrics).

**Task 3 – Hierarchies of maps –** The work based on lattice theory has continued although it has become incorporated into the work in WP3 on the topos foundation for persistence. A Heyting algebra for graphs has been developed and the theory is currently in a state such that the computation of indecomposables can undertaken and compared with the lattice theoretic constructions.

**Task 4 – Unified Theory –** Several of the approaches have begun to take on similar patterns. For example, the topos theory foundation utilizes tools developed in the lattice theoretic work. Furthermore, the algebraic tools developed in the first year are crucial for creating a more efficient algorithm for the self-map. Furthermore, there is a natural simplification/refinement operation, which seems quite universal.

**Main Achievements**

- **Task 1 –** Preliminary implementation, paper on the persistence of self-map accepted, the connection of Čech and Delanauy complexes through simple homotopies (which will be applied to the problem of the self-map). Initial algorithms for computing all the eigenvalues of a self map,
- **Task 2 –** The paper on persistent cohomology on recurrent systems has been written (along with preliminary experiments) and a full version is being prepared for submission.
- **Task 3 –** The preprint on the lattice has been refined and will be submitted shortly. The work in WP3 has yielded an alternate approach, which will be presented in an upcoming workshop.
- **Task 4 –** Several algebraic concepts (namely the pullback and pushout) are proving useful building blocks for more efficient algorithms. It has been observed that sheaves over a Heyting algebra can provide universal semantics for simplification/refinement.

**Deliverables**

**D1.1 Yearly Activity and Progress Report for WP1**

**D1.4 Prototype code to compute persistence of maps**

**D1.5 Prototype code for cohomology of recurrent systems**

**Milestones**

**MS2 Prototype code available**

**Contributing partners**

**IST, KTH, JSI, UJ, IIT**

**Overview for the next period**

In the next period, work will continue on the four tasks. For Task 1, a more efficient algorithm will be finalized and implemented with continuing experiments (on the social media data for example) as well as more applications to textual data in general to better understand the information

For Task 2, work will continue on understanding recurrent systems. We will into alternate methods of parameterizations as well as segmentation of dynamical data automatically for visualization and further analysis. Finally, we will look into how information on known recurrence/periodicity can be used in accordance with the parameterization to construct better metrics so that further processing may be done with fewer data points.

For Task 3, the indecomposables will be first computed of a rooted tree and then more general graphs, using the techniques developed in WP3. The next steps will involve dealing with non-commutativity (i.e. where maps do not agree).

For Task 4, a general algorithmic framework will be setup for computing persistence of different "shapes." The framework will be driven by the constructions already developed. Furthermore, we will search for common ``shortcuts" to improve efficiency in variants of persistence.

**Deviations from DoW (if any)**
N/A

## WP2 Multiscale Statistics

**Progress towards Objectives and Achievements**

In the second year, several key advances have been made.

**Task 1 – Topological Noise -** The results on central limit theorems for Betti numbers with an extension to persistent Betti numbers currently in preparation. Furthermore upper and lower bounds have been found for the longest bars in uniform noise in a d-dimensional hypercube.

**Task 2** – There has been work on use the Euler characteristic curve for threshold selection, which has been submitted for publication. Furthermore there has been work on the use of kernels on persistence diagrams to lift persistence diagrams into a Hilbert space, making it more useful as a feature in machine learning algorithms.

**Task 3** – We have looked at simplification of vector fields in 2D (with 3D in preparation) from a topological viewpoint. We have found necessary and sufficient conditions for simplification to be possible, showing it is possible even when Laplacian smoothing fails.

**Main Achievements**

- D. Yogeshwaran, Eliran Subag, Robert J. Adler, "Random geometric complexes in the thermodynamic regime," submitted – central limit theorems for Betti numbers

- R.J. Adler, K. Bartz, S.C. Kou, A. Monod, "Estimating Thresholding Levels for Random Fields via Euler Characteristics," submitted – use of Euler characteristics for estimating thresholds

- P. Skraba, B. Wang, G. Chen, P Rosen, "2D vector field simplification based on robustness," 7th Pacific Visualization Symposium, March 4-7, 2014, Yokohama, Japan. PacificVis 2014. (Best Paper) – simplification of vector fields with necessary and sufficient conditions

- A multiscale kernel for lifting persistence diagrams into a Hilbert space which can be used as features for machine learning algorithms

- Upper and lower bounds on the length of the longest bars in uniform noise

**Deliverables**

**D2.1 Yearly Activity and Progress Report for WP2**

**D2.4 Report on initial experiments on topological noise**

**Milestones**

**MS3 Reports on the preliminary experimentation**

**Contributing partners**

IIT, JSI, IST, UJ, KTH

**Overview for the next period**

The topological noise present in persistence, will continue with finalization on the bounds for the longest bars as well as the central limit theorems for persistent bars. There will also be further investigation into models for topological noise, for which we expect the additional understanding of persistence modules provided by WP3 will greatly help.

There will be further work towards identifying how qualitative features can help with model selection as well as additional work on persistence diagrams (and functionals) as features. For Task 3, we will try to provide stability results for smoothing processes as well as a better understanding of obstructions to simplifications (i.e. when smoothing will not destroy features).

**Deviations from DoW (if any)**
N/A

## WP3 Categorical Systems

**Progress towards Objectives and Achievements**

The ultimate goal of this work package is to gain a more fundamental understanding of persistence in its numerous forms, which is a necessity if it is to serve as a foundation for complex systems. Our progress within the three tasks are as follows:

**Task 1. Placing persistence into a categorical setting of topoi –** Within this task, looked at the construction of sheaves on the developed Heyting algebra. We have developed from this a time-varying set theory, upon which we can compute homology. The constructions needed have been developed in the first year (limits and col-imits). The work which is currently in progress is to place everything in an algorithmic setting and begin to compute examples with different set theory "shapes."

**Task 2. Statistical/machine learning sheaves –** We have begun formalizing the notion of semi-supervised based on topological and algebraic notions. This can help with model selection (WP2) but also is the first step towards considering locally encoded data in machine learning applications. Furthermore, we have found the partial order structure of the Heyting algebra gives a natural set of semantics for simplifying and refining topological and algebraic structures.

**Taks 3. Categorical dynamical systems** – We have a deeper categorical understanding of persistence modules and interleavings based on matchings. This complements the work on towers of persistence developed in the first year. Furthermore, it yields an indication that the space of extensions of persistence modules may have a simple combinatorial description, which will help with the development of models of topological noise.

**Main Achievements**

- Construction of a time varying set theory upon which we can compute homology. The first examples have been computed beginning the development of the algorithm for persistence with different shapes.
- A algebraic-topological framework for semi-supervised learning as well as general semantics for simplification/refinement (also referred to as low/high pass topological filtering)
- A deeper understanding of interleavings and persistence modules based on combinatorial notions.

**Deliverables**

**D3.1 Yearly Activity and Progress Report for WP3**

**Milestones**

N/A

**Contributing partners**

**UJ, KTH, JSI, IST, IIT**

**Overview for the next period**

In the next period, the algorithms for computing homology will be fixed and an initial implementation for a general algorithm will be provided. It may turn out that there may be some obstacles remaining. In particular, we may need to restrict ourselves to "shapes" which have a succinct representation.

For statistical/machine learning sheaves, we will further investigate our framework as well as attempt combine it with our semantics for simplification and refinement. Finally, we will experiment on the collected datasets to demonstrate multiscale phenomenon through these semantics and framework.

Finally, in categorical systems, we will continue characterize the Ext space of persistence modules which we believe have a simple description. This will aid in the development of models for topological noise in WP2. Furthermore, the concept of a self-map will be applied to less continuous data where we look for additional characterizations of behaviour of systems.

**Deviations from DoW (if any)**
N/A

## WP4 Validation and Applications

**Progress towards Objectives and Achievements**

**Task 1: Robotics –** In the area of robotics, we highlight an achievement of characterizing homotopic paths in configuration spaces. This utilizes work from WP1 in the form of a new simplicial complex construction as well as the code developed in WP4 in the first year. Discussions have also began on incorporating work from year1 in WP3 on local homology into this application.

**Task 2: Social Media** We have begun experimentation on collected and preprocessed social media and textual data including Wikipedia in different languages, metadata from the ArXiV preprint server, and Twitter data (for example, we can construct dynamic co-occurence graphs). The initial experiments have shown that a more efficient algorithm is needed. Therefore work has begun on a more efficient algorithm, which is close to completion. Another direction is the incorporation of the new complex construction to improve scalability. In the mean time, we have begun experiments on genetic data as well as epidemic data from InfluenzaNet.

Finally, an initial implementation of distributed persistent homology and cohomology is now available in the form of DIPHA (http://dipha.googlecode.com), showing that further scaling (to clusters of computers) is possible.

**Main Achievements**

- F. Pokorny, M. Hawasly, S. Ramamoorthy, "Multiscale Topological Trajectory Classification with Persistent Homology," Proceedings of Robotics: Science and Systems 2014
- Initial experimentation with Wikipedia, ArXiV, and Twitter data
- Application of persistence based tools to genetics data (Genetic Analysis Workshop 2014)
- Application of persistence to influenza data (Poster ECCS 2014)
- Development of the DIPHA library for distributed computation of persistence

**Deliverables**

**D4.1 Yearly Activity and Progress Report for WP4**

**Milestones**

N/A

**Contributing partners**

**JSI, KTH, IST, UJ, IIT**

**Overview for the next period**

Over the next period, we will incorporate more of the developed techniques to problems in configuration spaces. With a more efficient algorithm for the self-map there will be more experimentation on the social media datasets. Furthermore, the simplification semantics developed in WP3 will be applied to these data sets. Finally, work will continue on DIHPA and PHAT (and extensions) in order to provide a useful tool for computation and experimentation as well as work on alternate approaches of distributing computation. Finally the kernels developed in WP2 will be applied as features for genetics and influenza data.

**Deviations from DoW (if any)**

N/A

## WP5 Dissemination, Collaboration and Exploitation

**Progress towards Objectives and Achievements**

In the previous year, we have disseminated the project activities and results in related fields. There have been numerous papers published and many more submitted or to appear. The consortium as a whole has participated heavily in the IMA special thematic year on applications of applied topology as well as a larger presence at European Conference on Complex Systems furthering the initial exposure of applied topology to the Complex Systems community.

Collaboration has continued with the TOPDRIM and SOPHOCLES projects.

In terms of exploitation, the code has been made available for the self-map and the parameterization of periodic systems.

**Main Achievements**

- Numerous talks within the IMA thematic year
- Increased presence at ECCS
- Numerous talks and seminars increasing the exposure of the work done within TOPOSYS

**Deliverables**

5.3 Yearly Activity and Progress Report for WP5

**Milestones**

**Contributing partners**

JSI, IST, KTH, UJ, IIT

**Overview for the next period**

We will continue dissemination at related events with an even greater presence at ECCS next year, with perhaps another satellite. This will be in conjunction with verification with datasets, which are interesting to the Complexity Science community.

**Deviations from DoW (if any)**
N/A

### 3.2.3 Project management during the period

The project evolved as planned within the second year without any significant managerial or administrative issues.

The project is organized around yearly cycles, with deliverables at the end of each project year in form of reports. The second cycle was successfully concluded, with several of the tasks ahead of schedule.

The project consortium held numerous online meetings throughout the year between pairs of project members. Followed up by several visits throughout the year.

There were no changes in the consortium in the first year.

**Project meetings:**

There were one all-hands meetings for TOPOSYS

**TOPOSYS second year meeting (Vienna)**

The list of attendees for the meeting is provided in Appendix A. There were numerous meetings throughout the year, however mostly done as focused visits rather than large meetings. There was a natural synergy with the IMA thematic year, with many TOPOSYS focused meeting occurring within the workshops organized there since numerous TOPOSYS members were participants and speakers. Sharing of data as well as discussion has continued with the SOPHOCLES project. There has also been discussion with the TOPDRIM project with several of the TOPOSYS partners, which will continue in the third year. Outside DYM-CS, we have cooperated with the X-Like project on multi-lingual text analysis, in particular they have provided the preprocessing of the Wikipedia data as well as results on how linear methods work in these models. We have also co-operated with ACAT (ESF network) with another summer school planned in the final year.

The planning of work has proceeded without difficulty as progress has yielded results, which identify potential and promising directions.

The website is currently up-to-date and will be continue to be upgraded in the coming year. The ties with http://appliedtopology.org are proceeding with including as a repository for code.

## Appendix A

## 2nd year Meeting Vienna

1 Robert Adler
2 Ulrich Bauer
3 Herbert Edelsbrunner
4 Marc Ethier
5 Dejan Govc
6 Stefan Huber
7 Kristof Huszar
8 Mabel Iglesias-Ham
9 Grzegorz Jablonski
10 Mateusz Juda
11 Tomasz Kapela
12 Marek Krcal
13 Sunder Ram Krishnan
14 Marian Mrozek
15 Anton Nikitenko
16 Takashi Owada
17 Salman Parsa
18 Florian Pausinger
19 Pawel Pilarczyk
20 Joao Pita Costa
21 Florian Pokorny
22 Jan Reininghaus
23 Antonio Rieser
24 Primoz Skraba
25 Olga Symonova
26 Mikael Vejdemo-Johansson
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