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ProgettISTI 2016

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Abstract
*ProgettISTI research project grant is an award for members of the Institute of Information Science and Technologies (ISTI) to provide support for innovative, original and multidisciplinary projects of high quality and potential. The choice of theme and the design of the research are entirely up to the applicants yet (*i*) the theme must fall under the ISTI research topics, (*ii*) the proposers of each project must be of diverse laboratories of the Institute and must contribute different expertise to the project idea, and (*iii*) project proposals should have a duration of 12 months. This report documents the procedure, the proposals and the results of the 2016 edition of the award. In this edition, ten project proposals have been submitted and three of them have been awarded.*

Keywords
ProgettISTI

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1. Introduction

The Institute of Information Science and Technologies (ISTI), an institute of the Italian National Research Council (CNR), promotes the growth of its "young researchers" by means of initiatives aiming at encouraging the scientific production and promoting the visit to major international scientific institutions and research groups. All these initiatives are funded through self-taxation of all research laboratories of the Institute. These initiatives include

- the ISTI Young Research Award [1, 2] granted to the Institute staff of less than 35 years old with the best scientific production;
- the ISTI Grants for Young Mobility (GYM).

In 2016, a third and new initiative was funded: *ProgettISTI* aiming at supporting project proposals having principal investigators that are both young and belonging to diverse laboratories of the Institute. This new initiative complements the previously existing two since its primary goal is to give a recognition to ISTI researchers able to propose *innovative and cross-disciplinary research ideas* and formulate a *suitable implementation plan*. The cross-disciplinary nature is a distinguishing feature and aims at reinforcing and promoting *cross-laboratory collaborations*.

This report documents the procedure, the proposals and the results of the 2016 edition of the award. In this edition, ten project proposals have been submitted and three of them have been awarded. The report is organised as follows. Section 2 describes the approach underlying the award including the guidelines for preparing project proposals and the methodologies used for proposals evaluation. Section 3 describes the three proposals receiving the 2016 award. Section 4 provides an excerpt of all the ten project proposals participating to the award. Finally, Section 5 concludes the report.

2. Methods

ProgettISTI 2016 Edition was conceived and developed by a committee, appointed by the ISTI Director, to propose initiatives aiming at recognising and encouraging "young researchers" activities.

Award Committee

ProgettISTI falls under the initiatives promoted and developed by *ComInGio* ("Commissione Iniziative Giovani Ricercatori" / "Young Researchers Award Committee"). ComInGio was nominated by the Director of the Institute with the following duties:

- To design and develop a series of initiatives specifically conceived to support "young researchers" of ISTI;
- Prepare and develop the call for participation and the related procedures;
- Solicit nominations and assess candidates;
- Provide the ISTI Director with documents underlying the entire process and selecting the award candidates.

The Committee members were: *Matteo Dellepiane* (Chair) (Visual Computing Laboratory); *Paolo Barsocchi* (Wireless Networks Laboratory); *Leonardo Candela* (Networked Multimedia Information System Laboratory); *Vincenzo Ciancia* (Formal Methods and Tools Laboratory); *Andrea Esuli* (Networked Multimedia Information System Laboratory); *Maria Girardi* (Mechanics of Materials and Structures Laboratory); *Francesca Lonetti* (Software Engineering and Dependable Computing Laboratory); *Davide Moroni* (Signals and Images Laboratory); *Franco Maria Nardini* (High Performance Computing Laboratory); *Salvatore Rinzivillo* (Knowledge Discovery and Data Mining Laboratory).

Proposals Preparation

The participants to ProgettISTI were requested to describe their project proposal in a short document (no more than six pages) comprising the following:

- *Project Title*.
- *Proponents' name and affiliation*.
- *Abstract*: Short project description. About half page.
- *Targeted breakthrough and long-term vision*: Describe the breakthrough(s) that you are targeting to achieve. What is the long-term vision (scientific, technological, societal, other) that motivates this breakthrough? Explain how this breakthrough is an essential step towards the achievement of your long-term vision, in particular in terms of new forms and uses of information and information technologies. Describe the concrete objectives that you consider to constitute the proof-of-concept of such a breakthrough. The objectives should be those that you consider achievable within the project, in spite of the inherent risks. They should be stated in a verifiable form, including through the milestones that will be indicated in the "Implementation" part. About one page.
- *Novelty and foundational character*: Describe the state-of-the-art in the area(s) concerned, and the advance that the proposed project would bring about. Clearly describe the novelty of your proposal. About one and half pages.
- *Implementation*: Provide a detailed description of the scientific and technological approach or methodology by which you will attempt to reach your objectives. The section should be structured as follows: (*i*) Description: Provide a description of the scientific approach and of the main goals of the project, (*ii*) Resources to be committed: Provide an estimate of the resources needed to complete the project. In particular, discuss the needed personnel effort, and the eventual costs associated to dedicated equipment, (*iii*) WP structure and GANTT: Describe the goals and activities of the project via a Work packages structure. Provide also a GANTT chart with start and end time of all the tasks. About two pages.
- *Proponents CV*: In this section, proponents should include a short curriculum vitae and illustrate their current research activities (including, if any, three relevant publications at maximum). About one page.

Selection Process

A total of ten project proposals were received:[1]

- *DePAIS: Decorative Patterns Automated Identification System of Roman wall painting* (cf. Sec. 4 pag. 4) by M. Reggiannini (Signals and Images Laboratory) and E. Siotto (Visual Computing Laboratory);
- *DUE: Domus Universal Environment* (cf. Sec. 4 pag. 6) by M. Righi (Signals and Images Laboratory) and D. Russo (Wireless Networks Laboratory);
- *EMPATHY: A sensorized doll for improving the assessment and validation of non-pharmacological dementia care* (cf. Sec. 4 pag. 8) by D. Germanese (Signals and Images Laboratory) and F. Palumbo (Wireless Networks Laboratory);
- *GAMES OF DRONES: Self-organized cloud-based drone-assisted crowd tracking* (cf. Sec. 4 pag. 9) by E. Carlini (High Performance Computing Laboratory) and H. Kavalionak (Networked Multimedia Information System Laboratory);
- *Learning from Sequential Visual Data, a Deep Learning Hybrid Approach* (cf. Sec. 4 pag. 12) by F. Banterle (Visual Computing Laboratory) and A. Moreo Fernàndez (Networked Multimedia Information System Laboratory);

[1] An excerpt of each proposal is in Sec. 4.

- *PanFORTE: Photobased FOod Recognizer and reTriEval* (cf. Sec. 4 pag. 13) by F. Carrara (Networked Multimedia Information System Laboratory) and V. C. Monteiro de Lira (High Performance Computing Laboratory);
- *PEMBA: Population Estimation with MoBile cAlls* (cf. Sec. 4 pag. 13) by L. Gabrielli (Knowledge Discovery and Data Mining Laboratory) and A. Lulli (High Performance Computing Laboratory);
- *The Machine-Training: A data-driven personal trainer for cyclists* (cf. Sec. 4 pag. 15) by P. Cintia (Knowledge Discovery and Data Mining Laboratory) and M. Girolami (Wireless Networks Laboratory);
- *Topological Methods for Optimal Transmission Policy for Monitoring Service Based On Swarm of Drones* (cf. Sec. 4 pag. 17) by M. A. Pascali (Signals and Images Laboratory) and P. Cassarà (Wireless Networks Laboratory);
- *UTOPIA: Understanding the patterns of Abstract Human Mobility with Persistent Homology and Big Data analytics* (cf. Sec. 4 pag. 18) by L. Pappalardo (Knowledge Discovery and Data Mining Laboratory) and A. Villa (Signals and Images Laboratory).

The selection process was based on a two-phases process: (*i*) a *blind peer-review* phase, where the members of *ComInGio* analyses the project proposals (three reviewers per proposal) and produce an aggregated review report, and (*ii*) a *public discussion* phase, where the top 5 project proposals resulting from the peer-review phase are publicly presented to the ISTI staff and evaluated by the ISTI laboratory heads.

The following criteria were defined to assess and rank each proposal:

- Originality and relevance of the method and the expected results (up to 5 points);
- Interdisciplinarity (up to 5 points);
- Quality of the proposal and integration with the state of the art (up to 5 points);
- Organization of activities (up to 5 points);
- Creation or enforcement of collaborations (up to 3 points);
- Curricula of the proponents (up to 2 points);

Three reviewers were appointed to assess each proposal and produce a review report where they are requested to indicate their “confidence” in the review and give a score for each criteria accompanied by a text with the motivations for such a score. Once all the review reports were produced, the ComInGio met with to goal to produce the final assessment of the proposals, to produce an aggregated review report for each proposal, and finally identify the top 5 proposals suitable for the second evaluation phase.

On September 2016, the second phase of the evaluation took place to evaluate the following proposals: (*a*) EMPATHY: A sensorized doll for improving the assessment and validation of non-pharmacological dementia care; (*b*) GAMES OF DRONES Self-organized cloud-based drone-assisted crowd tracking; (*c*) Learning from Sequential Visual Data, a Deep Learning Hybrid Approach; (*d*) The Machine-Training: A data-driven personal trainer for cyclists; and (*e*) Topological Methods for the Signal Compression.

The three proposals described in Sec. 3 were finally selected for the award.

3. ProgettISTI 2016 Recipients

The recipients of the award are reported below.

The Machine-Training – A data-driven personal trainer for cyclists

Proposed by P. Cintia and M. Girolami.

The powerful tools of Data Science are disrupting sports world. The availability of cheaper and always smaller monitoring sensors opens up amazing scenarios for sports and performances improving. In this evolving environment, we propose the Machine-Training, an application for cyclists based on data-driven models providing a software personal trainer. By analyzing the efforts of a cyclist and thanks to the extremely precise measurements from heart-rate, power consumption and other biometric sensors, we aim to develop a system tailored to the needs of each individual rider. Cycling is an evolving sports, with lots of practitioners, from really young to older riders. The model we study and develop apply both for professional and amateur riders: data revolution has still entered the professional cycling world, but Data Science is yet to contribute to cycling performances analysis.

EMPATHY: A sensorized doll for assessment and validation of non-pharmacological dementia care

Proposed by D. Germanese (Signals and Images Laboratory) and F. Palumbo (Wireless Networks Laboratory).

In line with the effects of the aging society, the number of elderly with dementia is increasing. Dementia represents a chronic neurodegenerative disease which symptoms are associated to memory decline and other cognitive abilities impairment that lead to be not able to do everyday things. Moreover, some people become worried, angry, distressed, and violent. The dementia syndrome is one of the most burdensome conditions not only for the patients, who personally live such condition, but also for the caregivers. Therefore, novel approaches to at-home care, aimed to lower the burden of caregivers, are urged to be researched.

Doll therapy is a non-pharmacological dementia care that can help improving the mental status of the elderly. The endorsement of the so called “Empathy Doll” may allow these patients to focus their attention on a very simple task - caring for a doll - so avoiding all those confused thoughts that would crowd their mind and that are the reason for their behavior disorders. Several studies aimed at assessing the impact of the Doll Therapy on severe dementia patients. Despite the presence of a plethora of anecdotal and experimental evidence about its benefits, this is usually based on occupational therapists' observational, subjective measures, and non-rigorous procedures.

In the EMPATHY project, we propose a sensorized and networked doll for improving the assessment and validation of this non-pharmacological dementia care. Sensory data are elaborated by means of machine learning techniques that provide information on the use of the doll during the therapy and on its effects on the patient, in terms of stress levels. The doll will be also able to provide information about the general patient's psycho-physical state and its networking capabilities will provide remote monitoring of the effectiveness of the intervention by the primary (specialists) and secondary (relatives) caregivers, thus improving the quality of care and easing the burden for caregivers.

Learning from Sequential Visual Data, a Deep Learning Hybrid Approach

Proposed by F. Banterle (Visual Computing Laboratory) and A. Moreo Fernàndez (Networked Multimedia Information System Laboratory).

The task of Automatic Exposure Bracketing (AEB) consists of merging Low Dynamic Range (LDR) images at different exposures into a High Dynamic Range (HDR) image capturing all scene details. Since each shot is captured in a slightly different moment, AEB has to face two challenging problems: *image alignment*, i.e., correcting the (typically many) pixel misalignments; and *deghosting*, i.e., correcting the partially transparent or missing features resulted from moving objects. Our proposal emerges from the observation that LDR shots can be thought as a well-defined sequence with exposure and time being both dependent on the order in the sequence. Therefore, we plan to investigate the potential benefits for AEB that will likely result from the combination of Deep Convolutional Neural Networks (ConvNets) with Long Short-Term Memory (LSTM) networks. ConvNets and LSTM are two recently emerged Deep Learning (DL) architectures that are particularly fit to learn from images and sequential data, respectively. Since deep neural networks often require large datasets to deliver competitive results, we propose to synthesize a large dataset with realistic rendered images for the task. With the adequate net architecture and enough training data, our expectation is to improve AEB results in quality and time performance. This is because once the model parameters are optimized, the image generation is reduced to a simple forward pass through the net computations. We believe our architecture could be an interesting contribution not only in AEB, but also in the broader field of per-pixel prediction methods such as panorama stitching, medical image registration, etc.

4. ProgettISTI 2016 Proposals

DePAIS: Decorative Patterns Automated Identification System of Roman wall painting

Proposal submitted by M. Reggiannini (Signals and Images Laboratory) and E. Siotto (Visual Computing Laboratory).

Goal In the last years the scientific community extensively devoted its effort to find an answer to artistic image classification issues, without achieving a universal purpose solution. We propose to develop a Decorative Patterns Automated Identification System (DePAIS) aiming at the improvement of the current methods of artistic image classification, focusing on the specific case study of the decorative patterns in Roman wall paintings. DePAIS will be able to recognize objects in 2D images and identify the category to which the image containing the considered object belongs to. DePAIS architecture is conceived as the series of two subsystems respectively in charge of (*i*) processing the input data to extract relevant features and define the corresponding descriptors and (*ii*) processing the mentioned descriptors by Machine Learning methods, to classify the input data. Different algorithms will be implemented and tested for each subsystem, aiming at identifying one or more architectures fulfilling the recognition task in the most efficient and performing way. Within the scenario of an archaeological excavation DePAIS will represent an innovative tool to help the archaeologist in quickly figuring out the decorative pattern class of the discovered fragments of paintings. Furthermore, concerning the specific case of fragments that broke off due to natural events and detached from their position, DePAIS will represent a crucial tool to infer the original positioning within the painting frame.

Targeted breakthrough and long term vision In recent years, Cultural Heritage (CH) and Information and Communications Technology (ICT) evolved often crossing each other. With the development of ICT, CH found new directions of expression by exploiting the tools made available by research results. A relevant example of the intersection between these two fields is represented by the exploitation of Computer Vision (CV) and Computer Graphics (CG) methods for the identification and classification of artworks, i.e., a set of computation procedures that takes as input visual data relating to a CH work, extracts features that identify the peculiarity of that piece of work and returns a classification statement.

To this purpose, an interesting case study that the authors wish to consider as a validation test for the proposed project is the complex of the Roman wall paintings situated in the ancient Pompeii site. These paintings were classified in four styles (namely the 1st, 2nd, 3rd and 4th) by August Mau at the end of the 19th century [3]. Each one of these styles, more correctly defined as decorative patterns, is characterised by specific features that allow us to classify the paintings and retrace their history. In this circumstance, the main goal of the

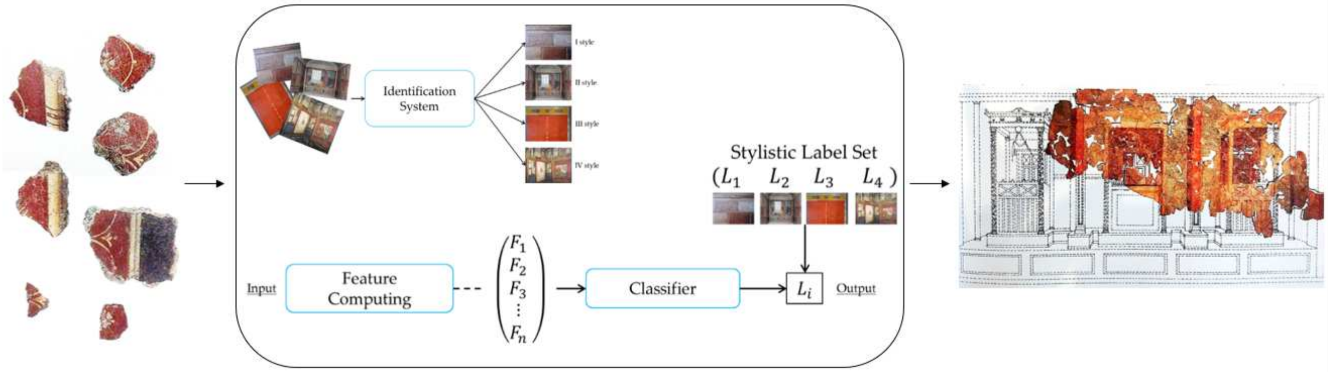

Figure 1. Graphical abstract of the Decorative Patterns Automated Identification System (DePAIS)

archaeologist is to assign the mural painting under examination to one of the available options, based on the analysis of the mentioned features.

Endowing a computing system with capabilities of performing the discussed task without human supervision is still an open research issue. The beneficial support of an automated 2D visual artwork classifier would arise in peculiar scenarios, here included archaeological emergency circumstances (mural painting recovery caused by sudden collapses) as well as the standard operative framework of an excavation campaign. To this purpose the authors propose to develop a robust classification system, namely the Decorative Patterns Automated Identification System (DePAIS).

The main goal of the project is to strengthen the currently available procedures to classify the decoration patterns of Roman wall paintings and provide further insights about the paintings fragments and their original positioning within the painting frame. The achievement of this target will happen through the fulfilment of two consecutive essential steps. First of all, DePAIS development will concern the design and the implementation of a system for the identification of relevant features that may be considered as discriminant factors for the Roman wall painting decorative patterns (shape, colour, textural patterns). This step will return a powerful set of descriptors, summarizing the most salient and distinctive attributes in the data. These descriptors will be employed to identify the specific category of the input data. This is the main goal associated to the second milestone of the project, that will concern the development of a system assigned with the classification task. The estimated features will be processed by means of Machine Learning methods, finally returning a stylistic label for the input data. DePAIS will provide a user friendly and open access system capable of automatically recognizing the decorative patterns category of the Roman wall painting.

Novelty and foundational character Up to the present, the scientific community extensively devoted its effort to propose solutions to image classification issues, nevertheless without achieving a commonly accepted universal purpose approach. Karayev et al. [4] proposed a method to classify the photographic style of images based on the exploitation of hand tuned features, such as histogram based features, combined with multi-layered network learned features. Many authors developed methods specifically conceived for the categorization of limited classes of painting images (traditional Chinese art [5], artist identification [6]) by first calculating relevant features and later exploiting them to train a neural network. An analysis of the available literature reveals a scarcity of solutions concerning the specific case of Roman wall paintings and generally speaking a lack of approaches integrating style identification procedures and object recognition methods to provide further functional tools to the archaeologist, such as systems to evaluate the fragment original position.

DePAIS will provide a state-of-the-art technology tool enriched by the development of novel algorithms, with potential skills for solving issues arising in different scenarios. In both cases of routine or emergency excavation it will help to speed up the recognition and validation of the painted plaster, while in the framework of a more sophisticated analysis it will support the operator in trying to figure out the original positioning of the painting fragment on the wall frame. This would be extremely helpful for the historian archaeologist concerned with the Roman wall painted fragments that have been detached and removed from Pompeii at the time of the Bourbons, and later transferred to museums around the world.

In addition, the system will represent a useful tool when exploited together with the historic documentation available from archival sources[2]. For example, in case of discovery of a fragment the system will be able not only to recognize the corresponding category of the decorative pattern but it will also put forward hypothesis on the original positioning of the fragment within the wall frame. The system will explore an available archive of wall paintings in search for the one exhibiting the highest similarity. Hence DePAIS will allow to identify the original work from which the fragment was detached. Moreover, the system will exploit jointly the

[2]See for example *Le Antichità di Ercolano esposte*, 9 voll., Napoli 1757-1792

recognition of the specific decorative pattern class together with the identification of descriptive features of the fragment itself (texture, shape, colour and eventually the recognition of an object, locally detected within the fragment) to put forward a hypothesis on the original spatial positioning of the fragment within the wall frame.

Implementation The essential structure of DePAIS is conceptually represented in the *graphical abstract* 1. DePAIS is based on a first processing step consisting in the extraction of salient features from the input data, followed by a stage in which the computed features are exploited to perform the classification.

The identification system described in the graphical abstract can be subdivided in two subsystems in charge of performing the two corresponding tasks in cascade. The first component is assigned with the task of processing the input image to extract a set of features that summarizes the informative content in the most proper and synthetic way. Proper descriptor typologies will be considered such as Scale Invariant Feature Transform [7] for the identification of robust interest points, primitive curves detector [8] for the assessment of the geometry attributes in the depicted scene, texture analysis [9] of the painting based on the use of Gabor wavelet filters and finally object recognition procedures to detect specific objects in the painting whose presence may be crucial to determine the decorative pattern class. Different combinations of descriptors will be tested with the aim of implementing a novel one, with enhanced performances.

The first stage returns a set of informative features that will be fed as input to the following component of the processing chain, i.e., the classification step of the system. This subsystem will be in charge of processing the estimated features coming from the previous stage with the purpose of returning a classification hypothesis for the input image. To this purpose several Machine Learning methods will be implemented and tested (including naive Bayes, decision trees and support vector machine [10]) against an authentic dataset, conceived and assembled within the project. A comparative study of the classification methods performance will provide an opportunity to evaluate novel classification methods, conveniently defined as functions of the available classifiers. To this purpose a boosting approach will be followed, taking advantage of previous research results. Indeed, it can be proved that a proper combination of weak performing classifiers give rise to a strong performing classifier. The main output of the classification step will consist in the estimated value of the stylistic label, representing the final output of the processing chain, providing a hypothesis statement on the stylistic category to which the input data belongs to.

DUE: Domus Universal Environment

Proposal submitted by M. Righi (Signals and Images Laboratory) and D. Russo (Wireless Networks Laboratory).

According to the vision of Ambient Intelligence (AmI), the most advanced technologies are those that disappear: computer technology should become invisible. All the objects around us must possess sufficient computing capacity to interact with users, the surroundings, each other and exhibit intelligent behavior. In home environments, Ambient Intelligence is the layer on top of the domotics. Its aim is to integrate isolated devices to achieve global, unified goals. Today, the lack of standard definition of application requirements for domotics has led to the development of a large number of ad hoc solutions which unfortunately are often limited and difficult to integrate. In order to make the advent of genuine AmI applications possible, there is a crucial need to define and develop a standard way forward.

The objective of this research project is to take steps in this direction by proposing an innovative intelligent system (DUE – Domus Universal System) based on: (*i*) a new universal distributed programming language (DUL – Domus Universal Language), (*ii*) a sort type used to describe devices and device I/O (dXML – Domus XML), (*iii*) an hardware abstraction layer (dHAL – Domus Hardware Abstraction Layer) and (*iv*) open source hardware/software philosophy. The aim of this system is provide an ad-hoc language able to implement coherence analysis of a domotic application at compile and at run time, and to easily describe the behaviour of domotic systems in relation to the events and contexts of users and devices. The sort type permits to DUL to be a modular language, this perfectly fits for home automation applications and permits a natural development of a text?based and/or graphical programming environment. Being an universal language, alongside to a middleware able to realize the fully interoperability among different and natively incompatible domotic systems and devices, this language can be used without taking care about the technologies of used devices. Being designed as distributed language, the system can share the computation loads according to the computing capabilities of the domotic network.

Targeted breakthrough and long-term vision The most significant breakthroughs that DUE wants to provide are:

- a new concept of programming language (DUL) with static componible types. It is an innovative solution in domotic programming that permits to verify at compilation time if the design of the domotic environment is coherent from a point of view of the programming language and of the domotic devices. This is obtained creating a new XML language called dXML that takes advantages of aspects of the functional programming paradigm. In particular, dXML models domotic devices and how they exchange message and DUL uses this models as types. Combining dXML with the functional paradigm, DUL specifies formal properties related to the interactions. In this way it is realized a strong static type check process and also the verification of the correctness of DUL code at run-time;
- the creation of an interoperability framework able to put in communication incompatible domotic sensors

and actuators of different technologies uniformizing them using an high level abstraction language that makes them able to share data. This permits to choose devices for their functionalities and not for their belonging technology, overcoming a big issue in domotics, and to integrate old and new domotic systems;

- to describe how the domotic devices react when defined events happened in the environment and/or defined user parameter are measured. Taking advantage of the interoperability framework and of the domotic devices, DUL permits to control the environment to implement and to describe events, and to develop new AmI (Ambient Intelligent) oriented algorithm. Moreover, predefined AmI algorithms in DUE can can take as input a source created using DUL to verify when described events happens, to combine and elaborate data and to verify, as example, changes in user habits;

- a developing integrated environment using a common operating system technique based on levels of abstraction (usually represented using onion skin analogy);

This project conducts, for example, to this long?term vision:

- DUL introduces an high flexibility to the entire system permitting for example, in a AAL field, to medical staff to describe in DUL the signs that are typical to prevent emergency or dangerous situations for the health of elderly;

- DUE permits a quick and low cost develop for specific problems such as systems for independence of elderly at home: exploiting domotic solutions implementing smart applications designed expressly for seniors, many daily activities can be automated to go beyond their physical limits and to improve their security and safety, making them more autonomous;

- dXML permits a modular description of the environment and a standard method to verify if the system is coherent.

This research project has surely a long term vision in terms of utility and in terms of research activities. In fact, the work can give a significant contribution, as example, to issues related elderly alone at home, to energy efficiency and so on. These examples are just some crucial issues for States and for EU. Moreover, as regard research activities, this project represents only a starting point that will permit the evolution of new intelligent algorithms, the creation of new domotic devices and new smart solutions for the wellbeing of human being. Finally, DUL represents a real innovation in the field of the programming languages and it can be easily extended for specific applications such as Smart Cities and IoT; in a long term vision it can became a general language for general purposes.

Novelty and foundational character During last years, the issue related interoperability among different domotic systems was faced in different ways. The literature offers many functioning and valid systems[3,4,5,6,7,8] [11] even if there is still not the definitive and standard solution. This is due principally because they do not provide enough innovation in programming method: to implement interoperability, most of the solutions in literature offer languages to solve specific purposes and they don't provide a coherence verification of all parts of the entire system. They are often based on XML and OWL, but almost none of them has developed an ad-hoc programming language for domotics with AmI capabilities.

Regard the current state of the art, DUE introduces:

- the innovative programming language DUL dedicated for domotics and an efficient and dependable system to design and to program domotic heterogeneous systems;

- the innovative componible sorted type [12] dXML;

- a modular approach in DUL that takes advantages of a new constructor called "parent-of". This constructor permits to extends the concepts of class and subclass that are typical of all object oriented programming languages, permitting to compose DUL functionalities and to create very malleable, flexible, type check verified system and highly reusable code;

- a domotic XML (dXML) able to describe and threat messages generated by a domotic system extending works such as [13, 14, 15]. dXML also takes advantages of the componible constructor [12, 16];

- a simple guideline for devices and interfaces in order to have each device as a type (or module) of the DUL programming language;

- the possibility to write the entirely code on a single computer and see how it is executed over the domotic system. The domotic system is represented as a IoT network where each device plays its own role reading and writing messages, and performing actions such as operate relays, electrical motors, reading sensors and so on;

- to distinguish the code that runs and that doesn't run on domotic devices. The system is able to compile the code optimizing it according to the recipient's device;

- the creation of virtual devices. Devices that are not able to execute DUL distributed code or that are not natively DUE (e.g., belonging to KNX, UPnP, ZigBee and so on technologies), are virtualized.

[3] Freedomotic `http://www.freedomotic.com/`
[4] Calaos `https://www.calaos.fr/en/`
[5] Domoticz `http://www.domoticz.com/`
[6] Home Assistant `https://home?-assistant.io/`
[7] OpenMotics `https://www.openmotics.com/`
[8] openHAB `http://www.openhab.org/`

EMPATHY: A sensorized doll for improving the assessment and validation of non-pharmacological dementia care

Proposal submitted by D. Germanese (Signals and Images Laboratory) and F. Palumbo (Wireless Networks Laboratory).

In line with the effects of the aging society, the number of elderly with dementia is increasing. Dementia represents a chronic neurodegenerative disease which symptoms are associated to memory decline and other cognitive abilities impairment that lead to be not able to do everyday things. Moreover, some people become worried, angry, distressed, and violent. The dementia syndrome is one of the most burdensome conditions not only for the patients, who personally live such condition, but also for the caregivers. Therefore, novel approaches to at-home care, aimed to lower the burden of caregivers, are urged to be researched.

Doll therapy is a non-pharmacological dementia care that can help improving the mental status of the elderly. The endorsement of the so called "Empathy Doll" may allow these patients to focus their attention on a very simple task - caring for a doll - so avoiding all those confused thoughts that would crowd their mind and that are the reason for their behavior disorders. Several studies aimed at assessing the impact of the Doll Therapy on severe dementia patients. Despite the presence of a plethora of anecdotal and experimental evidence about its benefits, this is usually based on occupational therapists' observational, subjective measures, and non-rigorous procedures.

In the EMPATHY project, we propose a sensorized and networked doll for improving the assessment and validation of this non-pharmacological dementia care. Sensory data are elaborated by means of machine learning techniques that provide information on the use of the doll during the therapy and on its effects on the patient, in terms of stress levels. The doll will be also able to provide information about the general patient's psycho-physical state and its networking capabilities will provide remote monitoring of the effectiveness of the intervention by the primary (specialists) and secondary (relatives) caregivers, thus improving the quality of care and easing the burden for caregivers.

Novelty Doll Therapy approach is based on the studies of Donald Winnicott [17], John Bowlby [18] and Bére Miesen [19]. The aim is to ensure the patients look after the Doll, as it were a real baby. Many studies aimed at evaluating the impacts of Doll Therapy for severe dementia patients. In [20], patients' activities and reaction were recorded on videotape. The recordings were viewed by skilled personnel and were classified into precise categories: no reaction, close observation, care giving, communication with other patients, wandering, agitating. In the study reported in [21], caregivers had to complete an impact sheet for each of 34 patients, based on five questions rated on a 1-5 Likert scale. Doll Therapy appears to generate positive outcomes for dementia patients [22] but such outcomes tend to be subjective narrative accounts of success and they are not supported by objective data [23]. Babyloid is a kind of sensorized little baby-robot. In [24], its impact has been evaluated, but also in this case the degree of acceptance of Babyloid by elderly patients was assessed by using questionnaires, not by means of measured, objective data. Moreover, it is not designed to take information about patient's psycho-physical status. Babyloid, as well as another sensorized robot PARO [25], is designed for patient's entertainment. The neuropsychological efficacy of PARO on dementia patients was evaluated by means of measured EEG data in a dedicated clinic. Instead, our goal is to collect measured neuropsychological efficacy data in situ.

What we intend to do in the framework of the EMAPTHY Project is: (*i*) to integrate sensors within an existing, commercial empathy doll, preserving its design and appearance; (*ii*) to collect objective data about the interaction of the patient with the doll, thus retrieving patient's stress levels and psycophysical status in general (vocal tone, strength in hands, fluidity in movements, probable falls, quality of sleep). EMPATHY addresses the above challenges from different point of views: (*i*) from the patient's point of view, it remains an entertainment tool, a "baby" to be looked after; (*ii*) from the relatives and occupational therapists point of view, it remains a tool for behavior disorders therapy, but also it becomes a watchful "eye" on the patient, thus decreasing their burden; (*iii*) from physicians' point of view, it may be a tool to monitor patient's psychophysical status (also remotely).

Implementation Besides the positive effects of the therapeutic use of the doll, the proposed EMPATHY system aims at enhancing the monitoring and networking capabilities of the doll. The EMPATHY system (Figure 2) is composed of a wearable device (a wristband) and a doll embedding different sensors and a gateway in order to communicate with the surrounding and the coupled wearable device.

From the hardware point of view, the EMPATHY doll will integrate:

- A microphone: to perform (by means of frequency-domain features) a Voice Stress Analysis (VSA);
- A temperature and relative humidity sensor: to increase the performance in detecting the use of the doll and to perform a rough estimation of the air quality of the environment when not used;
- A set of inertial sensors (3-axial accelerometers, gyroscopes): to detect the use of the doll and its positions;
- A set of Force-Sensitive Resistors (FSR): to detect the interaction of the user with the doll. The sensors will be placed in the hands, feet, chest and head of the doll;
- A gateway device based on Particle Photon/Arduino board: to collect data and send them to the cloud where they will be analyzed.

Regarding the wearable device coupled with the doll, it will provide:

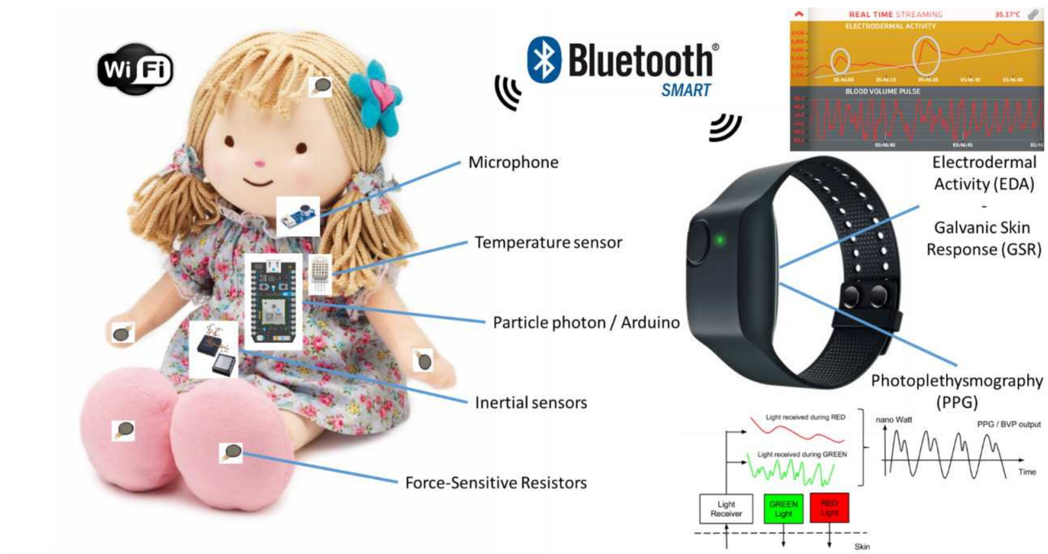

Figure 2. The sensor network provided by the EMPATHY system

- A PPG sensor: to provide continuous heart rate from which to infer Heart Rate Variability (HRV), Stress levels, and Relaxation;
- A 3-axis accelerometer: to detect movements and activity levels;
- A temperature and heat flux sensor: to detect activities and the physiological context of the user;
- An Electro-Dermal Activity (EDA) sensor: to detect arousal or excitement from the skin conductance.

From the data analysis point of view, the EMPATHY system will investigate machine learning solutions for both exploratory and predictive data analysis in order to detect the stress level of the user interacting with the doll. Figure 3 shows the overall data analysis chain and the deployment in the home environment and the planned cloud-based backend where all the data analysis algorithms will run. We plan to use the output of the wristband worn by the user during a short period of assessment of the system to train the supervised model only using the sensors embedded in the doll. This in order to provide a more unobtrusive tool, thus avoiding the use of devices to be worn during the therapy. We plan to use artificial neural networks (ANN) and in particular Recurrent Neural Networks (RNN) to build the stress levels recognition model. Information regarding the distress of the user during the therapy will be given to the caregivers monitoring the user remotely lowering the obtrusiveness of the therapy to the user.

GAMES OF DRONES: Self-organized cloud-based drone-assisted crowd tracking

Proposal submitted by E. Carlini (High Performance Computing Laboratory) and H. Kavalionak (Networked Multimedia Information System Laboratory).

Goal The goal of this project is the design, realization and evaluation of algorithms and communications protocols for scalable and effective dissemination of information and computation orchestration in a cloud-based drone-assisted infrastructure aimed at supporting self-organizing crowd tracking in civil contexts.

Targeted breakthrough and long term vision The detection and tracking of group of people in crowded scenarios is a fundamental aspect for a wide range of applications including surveillance, crowd behaviour modeling and public security. Crowd tracking in dynamic environments, however, is a highly challenging task and requires the integration of a multitude of technologies and algorithmic solutions. One crucial aspect in dynamic environments is the degree of adaptation that the sensors dedicated to the tracking (e.g., cameras, optical, etc..) are able to exploit. In order to cope with the highly unpredictability and dynamicity of crowds, and thanks to technological advancements in the field, we advocate that automated crowd tracking via Unmanned Aerial Vehicles (UAVs, i.e., drones) represents a viable and preferred option for crowd tracking in the near future. In this context, drones are involved in the crowd tracking as active and self-organizing entities that dynamically adapt to the crowd behaviour and environment conditions.

The actual realization of such scenario poses many challenges at many levels. The project will focus on the following challenges: (*i*) the dissemination of information among drones, that take into account hardware and environmental constraints, with the aim of scalability, low latency and robustness; (*ii*) the organization of the computational aspect, including the selection of resources, for the computational tasks related to crowd tracking. As the ultimate aim, the project aims at delivering an integrated set of algorithms, protocols and tools to tackle the aforementioned challenges in

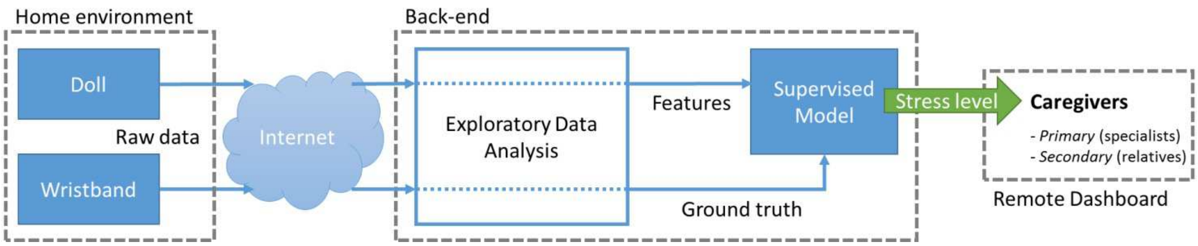

Figure 3. The sensor network provided by the EMPATHY system

a decentralized fashion, following the principle of acting locally but thinking globally.

Crowd tracking refers to the activity of monitoring, detect and possibly predict the behaviours of (large) groups of people in crowded scenario. Crowd tracking can be exploited in a number of both military and civil applications, such as surveillance of national borders to control immigration/emigration or controlling the flow of tourists in large cities.

The envisioned scenario is depicted in Figure 4. In such scenario, groups of persons move across the considered area. The area is potentially large and can contains obstacles such as trees or buildings. The area can already be equipped with static ground sensors devoted to crowd tracking that are interconnected via a wireless or wired network. The typical operations conducted by these sensors include the estimation of the crowd density, motion and behaviour. However, an infrastructure made solely of static sensors can be not enough to cope with unexpected events that can result from the inherent unpredictability of crowd behaviour and the environment, such as for example a broken camera or unexpected visual obstacles. In addition, ground sensors takes time to be installed, and therefore cannot be deployed in an unexpected situation if not foreseen in advance. Also, the monetary investment for the monitoring of a single event can not be justified in certain scenarios (e.g. research activities). Therefore we advocate a scenario in which sensor-equipped drones complement with the ground sensor network in order to resolve many of the aforementioned issues. In such scenario a fleet of drones flies above the area, each drone connected to each others and with the network of ground sensors. Drones can be used as highly-moving computational and storage units, allowing for a dynamic access point toward remote cloud datacenters. They can be deployed to different locations on demand, with a very short notice and without requiring a dedicated static infrastructure placed beforehand. Their behaviour can be reprogrammed while in mission, making them suitable to adapt to fast and unpredictable events within the same mission.

In the light of aforementioned vision, the project focuses on two tightly connected aspects:

- a scalable and decentralized support for drones-to-drones and drone-to-ground communication, with the aim of disseminate information about both the state of the sensor and behaviour of the crowd in the drone-assisted crowd tracking network.
- an effective and QoS-aware orchestration of the computation related to crowd tracking in terms of resource selection, task management, and offloading to remote computational resources, organized by means of the Cloud Computing paradigm.

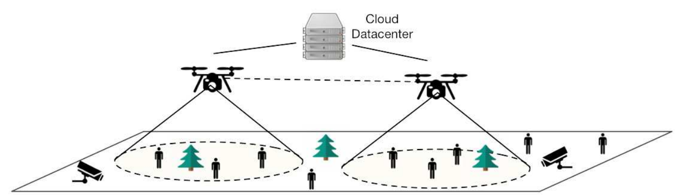

Figure 4. The envisioned drone-assisted cloud-based crowd control scenario

The objective of the project is to provide an integrated software architecture that includes the functionalities described above. The evaluation will be conducted by means of extensive simulations in a realistic crowd tracking scenario that will be designed during the project, and in which a crowd of at least 1000 persons will be successfully tracked by a fleet of a least 10 drones.

Novelty and foundational character *Offloading to cloud computing* In the last years, many approaches have dealt with scenario in which computation is offloaded from mobile devices to cloud datacenters [26]. The benefit of such offloading is to improve the capacity of mobile and thin devices, usually limited in terms of CPU, memory and battery life, so that even simple devices can run complex and demanding applications. Among the many proposals, MAUI [27] and CloneCloud [28] are based on virtual machine migration and focuses on offloading of computation from mobile devices to remote servers at execution time, allowing the developers of applications to decide which computation can be offloaded.

In terms of computational resources, Cloud computing could represent an ideal back-end solution to manage the computation related to crowd tracking and image processing [29]. However, due to the large amount of data collected, which needs to be transferred to the cloud, and the inherent dispersion of entities that performs data collection, it can be infeasible or inconvenient to transfer the computation toward a large remote datacenter. This is specially true in out envisioned scenario, as the crowd behaviour shall be identified fast such to allow the drone fleet to adjust their position. The help of the remote full-blown Cloud computing datacenter can still be invoked in such cases when the local power is not enough, or to increase its precision in tracking. In such cases (part of) computation can be offloaded to the cloud datacenter. This scenario points toward the case in which drones assume the role of *cloudlet* [30], and ground sensors the role of mobile devices. In the cloudlet model, mobile devices offload their computation to cloudlets, which are relatively small computational units connected with the full blown remote cloud server. Cloudlets are deployed locally to the area of interest and often placed in common and crowded areas to achieve physical proximity with mobile devices. This aspect provides devices with low latency and high bandwidth connections, thereby allowing an interactive response for demanding applications.

The approaches defined for cloudlet currently developed target mobile devices like smart-phones or laptops. The difference with respect to our scenario is the fact that offloading does not affect the context of the cloudlets or the devices. Instead, in our scenario the offloading also affects the behaviour of a drone, which in turns can affect the whole fleet. In other terms, the decision whether to offload is not only affecting the quality of the application but potentially affects the crowd tracking scenario as a whole, for example by modifying the behaviour of the other drones in the fleet. Therefore, we plan to adapt existing or design new distributed algorithms that: (*i*) orchestrate the computation also considering the effect that offloading can have in all the entities related to the crowd tracking, and (*ii*) perform fast and effective brokering of resource [31], in order to guarantee the quality of service demands from the crowd tracking tasks.

Epidemic protocols Epidemic protocols (often referred to as *gossip*) are a family of very effective, flexible, yet simple tools for exchanging information and for overlays creation and management purposes in a networked environment. The effectiveness of these protocols relies on the fact that each entity of the network acts on a pure local information basis. The effectiveness of gossip is highlighted by the fact that, using only local interactions, participants are able to achieve global results, like reaching a consensus on the value of a data item. Gossip protocols offer the advantage of reducing the number of messages required to spread information without any point of centralization, making them scalable even with networks composed of highly dynamic entities. Due to their flexibility, gossip protocols have been used in a wide range of fields, such ad-hoc [32] and peer-to-peer [33] networks, proving to be robust enough to be used in highly dynamic scenarios.

In context similar to the one of the project, there have been several attempts to use epidemic style drone-to-drone communications. In [34] authors considered an urban scenario in which the transport level of the network is realized by means of a gossip protocol. In [35] a gossip protocol is used to update the reprogram a swarm of sensor by gossiping pieces of the code throughout the network with the help of drones. The existing approaches focus on the routing problems, but they do not explore how to organize the application-level context exchanging for an effective and cost-aware dissemination of the information. In this project, we plan to go beyond by the state-of-the art by proposing an comprehensive stack of gossip protocols that works collaboratively at many levels. Lower levels keeps the connectivity and assure the routing, while upper levels self-organize the exchange of communication and the structure of the overlay network to achieve application-level goals that aim toward crowd tracking.

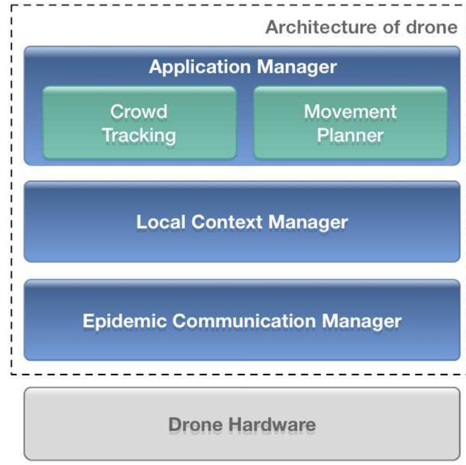

Figure 5. High-level architectural view

Concept and Approach The final goal of the project is the realization of several components of the internal software architecture of drones participating to the crowd tracking. An high level overview of a preliminary architecture is depicted in Figure 5. On the bottom level of the architecture lies the drone hardware. We assume drones to be equipped with sensor for manoeuvrability (e.g., GPS, rotors controller) and image acquisition (e.g., cameras). We also assume they are equipped with relatively high battery capacity and computational power. The *epidemic communication manager* module will take into account the management of the drone-to-drone and drone-to-ground communications. Since communication is a costly operation, a particular care will be taken such that information dissemination will be done in an effective way, maximising the usefulness of information sent. The component will also take into account the unreliability aspects of the communication channels. To achieve these results, will be used communication protocols inspired to epidemic communication to disseminate information among the fleet of drone. The information obtained by means of the communication module will feed the *local context manager*. The context models the view of a drone about its surrounding, and contains information of other drones, ground sensor and about the crowd. The information of drones range from their positions, direction and speed, to battery level and computational capacity. An important features of the context is the exploitation of prediction algorithms to predict ahead the context, which will allow the drones to plan in advance their behaviour so to possibly anticipate or avoid critical situations. On the top of the stack, the *application manager* orchestrates the computational aspect of the drones. The computational tasks can be related to the decentralized organization of the fleet and crowd tracking. The *movement planner* decides the trajectory of the drone considering the local context, and in such a way to globally optimize the area covered by the fleet. The *crowd tracking* module will employ image recognition algorithms already existing in literature in order to acquire information and build models of crowd behaviour. The application manager will coordinate the computation underlying these modules by deciding whether to execute the related tasks locally or remotely according to the local context.

Learning from Sequential Visual Data, a Deep Learning Hybrid Approach

Proposal submitted by F. Banterle (Visual Computing Laboratory) and A. Moreo Fernàndez (Networked Multimedia Information System Laboratory).

Goal The project goal is to improve on the task of Automatic Exposure Bracketing (AEB), i.e., merging Low Dynamic Range (LDR) images at different exposures into a High Dynamic Range (HDR) image capturing all scene details. Improving on AEB will likely be a solid step towards more complex per-pixel prediction problems such as medical images registration, panorama stitching, etc.

Targeted breakthrough and long term vision The project aims at improving the task of AEB, i.e., merging LDR images at different exposures into a HDR image capturing all scene details [36]; see Figure 6. Improving on AEB will likely be a solid step towards more complex per-pixel prediction problems such as medical images registration, panorama stitching, etc.

Figure 6. An example of HDR imaging from a sequence of LDR images at different exposure times

More concretely, we plan to pursue our goal by focusing on two important artifacts:

- *Ghosts removal*: moving people/objects in different exposure photographs can appear in slightly different parts of the scene, because all exposure images cannot be captured in one shot.
- *Camera misalignments*: camera sensors are very sensitive. For example, we can have a misalignment between two consecutive images of a few pixels just by pushing the capture button of a camera on a tripod.

Short-term Objectives: The concrete objectives, we plan to address during this project, are: (*i*) *Dataset*: deep neural networks require large datasets to converge to a high-quality solution. We plan to generate a very large dataset by rendering LDR images and the ground truth HDR outputs; (*ii*) *Neural Model*: design a model that is sensitive to visual information and ordered sequences; (*iii*) *Training the net*: we plan to train the model in two steps. Coarse-grain training: the first one will be carried out on an early prototype of the dataset. Fine-grain training: this step will take the model parameters and will use real examples to fine-tune the model parameters; (*iv*) *Article*: we plan to write a scientific communication of the results achieved during the project.

Long-term Objectives: We believe that our proposed model can be adapted to tackle other important problems in imaging, which share the sequential nature, such as (*i*) Medical imaging: aligning a patient CT/RMI images to improve tracking changes before and after a therapy; (*ii*) Panorama stitching: panoramas are computed by aligning images captured at different times (though with a fixed shutter speed), and they suffer from similar artifacts of AEB; (*iii*) Mobile exploitation: To use this technology on mobile devices in order to empower users to capture the real-world in real-time.

Related Work *AEB*: The current state-of-the-art are the Sen et al. algorithm [37] and Hu et al. algorithms [38]. These methods can both manage camera alignment and deghosting at the same time creating high-quality images, by both following a patch-based strategy for reconstruction. Patch-based reconstruction is typically a very slow task because nearest neighbors queries are needed. However, these methods exploit PatchMatch [39] to speed queries up. Although these methods can solve the AEB task in challenging cases, they present some limitations: they are not straightforward to implement, fairly slow (e.g., order of minutes), require a lot of memory (e.g., order of gigabytes), and difficult to map on the GPU.

Convolutional Neural Networks (ConvNets) are pushing the state-of-the-art in many related tasks such as super-resolution [40], image denoising [41], or optical flow detection [42]. One relevant ConvNet to our project is FlowNet [42]. This model is devoted to optical flow recognition, i.e., keeping track of moving objects or the camera viewpoint.

Long Short Term Memory (LSTM) are Recurrent Neural Networks (RNN). They are particularly effective in learning from sequential data. LSTMs are the current state of the art in many NLP tasks such as dialogue generation, language modeling, or text prediction. Since an LSTM can learn from sequential data, we believe they will also be able to learn from sequences of images at different exposure time and to track moving objects.

Approach The model we propose is a concatenation of a ConvNet block with an LSTM block; see Figure 7. The expectation is that the ConvNet block models the visual-related part of the problem, whereas the LSTM adds sensibility to dynamics; i.e., moving camera and people/objects. Each LDR image is given as input in the same order as it appears in the sequence. The ConvNet block first processes an image, and passes its convoluted outputs to the LSTM, which further processes it taking into account the previous history in the sequence.

The initialization of the model parameters is an important factor in achieving high-quality solutions to non-convex optimization problems. In fact, it is known that starting from a naive random initialization is often prompted to end up reaching suboptimal configurations. In order to reach better configurations, the net is usually pre-trained in a slightly simpler task. The parameters are then fine-tuned through back propagation on the real task. Therefore, we propose to generate/collect two datasets:

- Pre-training dataset: we will generate synthetic images at different exposures with ground truth using a physically-based renderer [43]. We will generate cases tackling different problems such as varying speed for moving objects, varying number of moving objects (from static to cluttered scenes), varying camera position (from static to large displacements), and combinations of previous cases.
- Fine-tuning dataset: we will collect real data from the Internet (multi-exposure datasets) in order to improve the last stages of training.

Novelty: Our approach is motivated by the observation that FlowNet obtains better results when mirroring part of its ConvNet architecture, allowing the model to operate on two input images. The novelty in our project, compared to FlowNet, is that it goes one step further by combining the output of a single ConvNet with an LSTM. We believe this architecture will better model the information of the problem without the need to duplicate part of the ConvNet for each image in the sequence, thus requiring less parameters to optimize. Furthermore, with an LSTM modeling the memory, the sequence of LDR images is no longer restricted to be of a fixed length. To the best of our knowledge, LSTMs have not been applied to sequences of images so far.

PanFORTE: Photobased FOod Recognizer and reTriEval

Proposal submitted by F. Carrara (Networked Multimedia Information System Laboratory) and V. C. Monteiro de Lira (High Performance Computing Laboratory).

A healthy life requires a good nutrition. Healthy eating is fundamental to manage and prevent diseases, such as food intolerance, obesity or allergies. Knowing how many calories and nutrients a person should eat and drink is an important step to maintain a healthy diet and lifestyle. However people don't have time or energy to calculate everything he/she is eating. Furthermore, people can choose special diets range from religious practices, ideological beliefs to allergies, special diets and food sensitivities. The need for technological support for healthy eating is witnessed by the many projects that have addressed wellness behaviors such as healthy eating. Recently, the EU through the Horizon 2020 (Work Programmes for 2014/15 and 2016/2017) closed a "call for challenge" for a 1 million euro prize to develop an affordable and non-invasive mobile solution that will enable users to measure and analyse their food intake.

We propose *PanFORTE*, supporting a personalized healthy-meal recommender system designed to meet individuals' health goals, dietary restrictions, and fine-grained food preferences. The long term vision of PanFORTE is a mobile solution that through the camera of smartphones efficiently analyses food items and dishes, providing nutritional information and potentially harmful ingredients such as allergens. This kind of interaction based on pictures, e.g., taken using a smartphone, is very popular, also thanks to the social media and food journalism, and may lead to the developing of diet tracking and food recommendation systems which require minimum effort from the user. Thus, translating into a better insight of food consumption given to the user. The proposed project wants to develop methods to combine the image recognition capabilities tailored to food with the knowledge base retrieval, ranking and recommendation tasks that can help the users in improving their food choices. Both these topics will gain from their reciprocal integration in different ways. Visual food recognition will drastically reduce the cognitive load for the user when food logging, therefore improving the quality of personal recommendations; in the other way, user feedback on recommendation and food logs can be used to increase the visual food recognition performance. In the long term, the interdisciplinarity of this topic is not only limited to recommendation systems and visual computing as in this project; future developments can potentially involve the medicine and nutritional experts in order to analyze current trends in food consumption, and improve future recommendations for a good and healthy nutrition. The integration with social media can also boosts new possible applications trying to understand the new food trends or the sentiment of users towards certain food or diets.

PEMBA: Population Estimation with MoBile cAlls

Proposal submitted by L. Gabrielli (Knowledge Discovery and Data Mining Laboratory) and A. Lulli (High Performance Computing Laboratory).

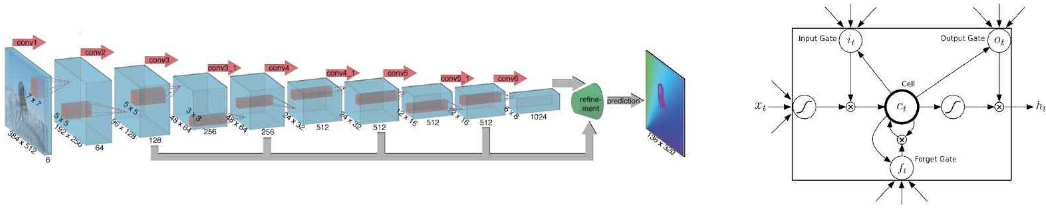

Figure 7. Model architecture: (a) the ConvNet block (inspired by FlowNet [42]); (b) the LSTM block

Targeted breakthrough and long term vision Last years have seen a great increase in the use of mobile devices. Everyday, each individual is using these devices for many purposes and it is generally accepted that almost the whole population has at least reduced the burden on their utilizations.

One of the major contribution is to think how to use such data in ways that they are not originally conceived to be used. For instance, the main goal of our project is to provide population estimates making use of the great amount of data collected by companies providing mobile services. These open new challenges in many different scenarios from scientific, to technological and societal. We think that extracting the information about the calling behaviour of the individuals and tessellating the space in the different districts permits to identify if a person lives in a district, is a commuter or is just an occasional visitor. Previous studies assume that if an individual makes a large amount of calls in any moment of the day is a resident, whereas if he is calling only in the working hours is a commuter [44].

The above depicts new scientific and technological challenges. Mobile data are produced only when the mobile phone is used, due to this we need to statistically validate the data and provide countermeasures when we do not have enough data for some individuals. In this scenario we have major questions such as how to recognize if poor data are characterizing a visitor or just a resident that perform a small number of calls. About the technological challenges is important to define a scalable and high-performances approach. Mobile data are characterized by huge size, due to this we need to improve the state-of-art approaches regarding clustering and distributed algorithms in order to provide a result in a reasonable time.

In addition, we aim to apply this approach also to support an advanced provisioning of cloud services. The optimization of such services requires to know (or at least be able to estimate) the amount of individuals expected in an area in order to allocate enough resources and to predict peaks of requests in advance. This is definitely a very active and hot research topic, as in the cloud community, especially when taking into account the services accessed by means of mobile devices, there is an increasing interest in the conception of the approaches aimed at forecasting the behavior of users and applications.

Finally, the project has multiple societal objectives. The first one is to provide a population estimator making use of clustering-based users' categorizations. This is the first step to provide indicators capable of producing results in less time with respect to common population statistics approaches. Also, we think that an important evolution is to provide an instrument capable of providing indicators with a continuous streaming of data. This permits to monitor the evolution, in particular, of visitors in each district.

Novelty and foundational character Mobile phone traces have been utilized to monitor the traffic in cities and analyse tourists movements. In particular two popular works focus on this issues for the cities of Rome and Graz [45, 46]. Other researches identify places that could be considered as meaningful by mobile users as workplace and home points. In addition, a plethora of works, including the winner of the Nokia Mobile Data Challenge [47], build predictors able to determine the next position of an individual given her/his current context. The idea of exploiting mobile phone data for estimating density of population has been investigated by Deville et al. [48] that propose a framework called MP. According to such methodology, the density of a population is estimated as a function of the night-time phone calls occurring in a given area. However, we think that it is more informative to use the entire calls profile instead of a simple rule-based approach. As an example, it would be cumbersome to define rules able to characterize individuals that are Commuters or Visitors. To overcome the aforementioned limitations, in a seminal work Furletti et al. [44] defined how to build individual profiles based on mobile phone calls. Such profiles characterize the calling behaviour of a user, in different time slots. By analysing these profiles, it is possible to identify three categories of users: Residents, Commuters or Visitors. Sociometer [49] focuses on this characterization to aggregate users having a similar calling behaviour with the K-means clustering algorithm. The centroid of each cluster is compared with predefined archetypes representing the categories of interest, then, each cluster is classified by means of the associated archetype. Our project aims to advance the achievements of Sociometer in the following areas as well as introducing a novelty in the approach:

- perform experiments on a real scenario in a large Italian region (Tuscany);
- provide a scalable approach able to process a sensibly larger collection of data;

- define personalized similarity metrics supporting more accurate classification of clusters;
- automatically remove outliers;
- avoid the definition of the number of clusters in advance, as happens with K-means;
- work with a continuous stream of data and provide insight of changes in populations;
- adapt to cloud environment and provide estimates about narrow areas to scale up and down resources;
- make the clustering completely unsupervised by instrumenting the algorithm to automatically choose the parameters instead of requiring user inputs.

Initially we need to collect and aggregate mobile calls data. Then, for each couple (individual, municipality) we build an Individual Call Profile (ICP) characterizing the calling behavior of the individual in the given municipality. One of the major challenge that will be faced by this project is the clustering of individuals described by an ICP characterized by low values. This may occur in two very different cases. The user could be either an individual performing few calls because is a Visitor in the given municipality or is a Resident that perform very few calls and seems similar to a Visitor. To this end, we plan to extend the ICPs with aggregated information that may indicate if the individual in the same time slot is present in a different municipality.

Figure 8 gives an overview of the whole PEMBA's analytical process. For each mobile user we build an ICP (see column A). Then, we generate a graph of ICPs. At the bootstrap, we randomly link each node to few other nodes (see column B). Then, the algorithm iterates, starting from the initial graph, adjusting the neighbourhood of each node with most similar nodes. In the following stage, are pruned the edges connecting nodes which similarity is below a given threshold parameter (see column C). The resulting clusters are the connected components derived from the pruned graph (column D). It is worth to notice how in this phase the nodes without neighbours are identified as outliers (Situation represented in Figure 8 by node #2). Finally, for each cluster it is generated an exemplar (column E), used by the automatic classifier to label the clusters as Resident, Commuter or Visitor. An important characteristic of our clustering algorithm is the possibility to inject an arbitrary similarity metric. This permits to adapt the similarity metric to our data instead of the algorithm.

The Machine-Training: A data-driven personal trainer for cyclists

Proposal submitted by P. Cintia (Knowledge Discovery and Data Mining Laboratory) and M. Girolami (Wireless Networks Laboratory).

Goal This project proposal envisages Machine-Training, an application for cyclists based on data-driven models providing a software personal trainer. By analyzing the efforts of a cyclist and thanks to the extremely precise measurements from heart-rate, power consumption and other biometric sensors, we aim to develop a system tailored to the needs of each individual rider, both professional and amateur riders.

Targeted breakthrough and long term vision Sports science is discovering the power and the possibilities of Data Science and Internet of Things. Biometric sensors are becoming cheaper and smaller, providing performance monitoring tools with a precision never seen before. Such a data revolution represents a breakthrough to the evolution of the sport science: collaboration across researchers from different areas are starting, aiming to join expertise in different disciplines such as physiology, computer science and data mining.

Cycling is the one of the sport that is mostly involved such a data revolution, it is one of the most practiced sports in the world with events attracting thousands of participants of different skills. Thanks to the benefits of cycling for the health, more and more people are approaching cycling, often becoming passionate and devoted racers.

As a matter of fact, each rider is nowadays able to record lots of different aspect of his effort, from the speed, the heart-rate to power consumption. Such data are gathered by exploiting tiny and affordable sensors that second by second, offer source for complex data analysis task to be done post-performance.

Although the plethora of data available, we think that the most important challenge is yet to be faced. Our vision is to understand and to suggest, precisely and timely, the best training pattern for each athlete. What is the secret to get the best from each kind of cyclist, from younger to older, from fattest to thinner and so on.

The cycling community would take advantage of a smart training software precisely tailored on their physiological characteristics. We foresee a personal trainer always available, that is based on all the biometric data of the rider in order to provide support in real-time along the training sessions. Training planning, real time support, timely hints and suggestions to boot the performance of the rider, day by day, stage after stage.

Professional riders are monitored a personal team of trainers and physicians, planning the training sessions as well as the rides. Differently and to the best of our knowledge, such personal training system is still missing, in particular for the general audience. The rapid diffusion of affordable biometric sensors is opening up to new possibilities for every athlete. This is happening across all the sports world: the Tennis Commander app[9] is remarkable example of low cost technology applied to tennis. The Tennis Commander is based on a Bluetooth positioning system and on app for Android smart watches recording the behavior of the athletes. As for exam-

[9] www.tenniscommander.com

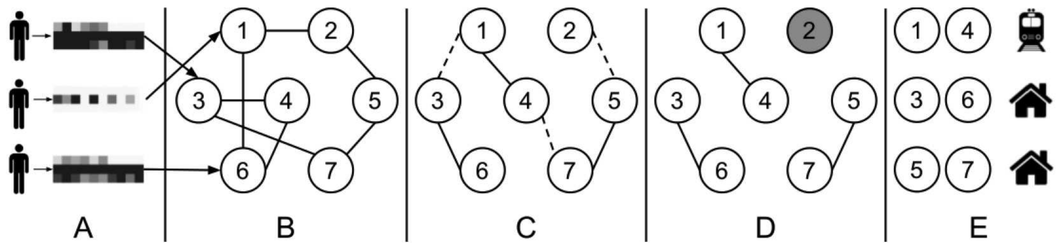

Figure 8. PEMBA analytical process

ple, it records the player position, the power of the shots and more generally everything measurable through accelerometers. Another product following this trend is SuperOp[10]. It is a wearable blood pressure tracker connected with an Android/iOS app able of assessing the level of physiological stress that an athlete can sustain during the next workout. It is based on a data-training task, where the heart-rate and the blood pressure of the athlete is recorded every day to learn his/her intrinsic characteristics. In turn, the app provides to the athlete the level of stress he/she can sustain for the next day so that to achieve a valuable training outcome.

Novelty and foundational character The striking proliferation of data that characterizes our modern era is now affecting even another interesting aspect of our society: the complexity underlying sports performance is starting to be unveiled through the powerful tools of data science.

Nowadays, the perspective of securing a competitive advantage versus their peers is driving major sports organization to collect and analyze more and more data on their athletes: individual performance, coaching or managerial decisions, game-based events, and the list goes on. Obviously, since such data represent a great wealth in terms of competitiveness for sport organizations, they are rarely made public.

The availability of high connected low cost sensing technology, also refereed to as Internet of Things (IoT), is another major key to share the power of Data Science among every kind of athlete, including amateurs, young riders and everyone who is only aiming to reach a good fitness level. Tracking every single performance is not a task only for professional athletes anymore. Conversely, Data is making every sports more enjoyable for everyone. Cycling is already one of the most connected and IoT-ready sports ever (See [50]). A world class rider monitors continuously his/her training/racing activities, in particular he/she collects the heart-rate ,the power consumption (in Watt), the cadence, the speed, the elevation gain and the slope. And this set of sensing information is going to increase in size, in frequency as well as in accuracy. As for example, new measurements such as oxygen consumption or blood lactate are near to become common metrics to analyze. The continuous monitoring opened up new challenges in sports science, physiology and, obviously, data science. In [51] a six-year long world class cyclist monitoring has been reported, with a precise estimation of many performance parameters able to describe the evolution of such rider from the first years of racing until the achievement of a top-10 standing at Tour de France.

Today, every rider has the possibility to exploit the world of data. This change, in our vision, is given by two enablers. The first enabler is the diffusion of Bluetooth (or Ant+) sensors for tracking the heart-rate, the positioning or the power consumption. These devices are more and more affordable and the are compatible with most of the smartphone, providing a powerful tool to monitor and track the fitness of each athlete. The second ingredient, is the proliferation of the so-called fitness social network offers such as Strava, Runtastic, FitBit, Garmin Connect and many more. Such social networks aggregate the sensing information gathered so that to reveal the patterns underlying success in sports. Indeed, through such platforms users can collect, monitor and share with friends their sports performance, the diet, and even the burned calories. Since such data are generally made available by public APIs, this enables researchers to download and analyze information about thousands of professional and amateur sportsmen, giving an unprecedented opportunity to answer very fascinating questions:

- What are the main factors that shape sports performance?
- What are the characteristics that distinguish successful sportsmen?

A first attempt to answer to such questions is given by the authors of [52] in which they present an analysis with data mining techniques of 30K cyclists highlighting common (and successful) training patterns among Strava[11] users. So far, sports scientist relied on applied physiology to reveal the secrets of fitness. The main challenge, in sports, is to understand how to improve performances of an athlete. In [53] authors propose a model to assess the capacity for cyclists to repeat hard efforts; such a model could provide a "live" indicator for each athlete, useful to get an estimation, in real time, of the sustainable effort according to the efforts previously faced. Common training pattern, though, are the results of studies performed on, usually, a dozen of athletes. A shift in this perspective is provided by the increasing availability of data, coming from more and more athletes and recorded with always more sophisticated tracking devices.

[10] `www.super-op.com`

[11] `www.strava.com`

Our proposal differs from the solutions already available on the market for several reasons.

Firstly, we go live! In fact, we aim at designing a real-time personal trainer able to timely suggest to the rider the best strategy to follow and some useful hints along with the ride. Secondly, our system is tailored on the rider. Our goal is to learn the behavioral patterns of the riders such as his/her average speed at different conditions, statistics of his/her cadence during the climbs (standard deviation, average, the median), the time series of the heart-rate. Then, we elaborate such enriched profile of the rider so that to suggest to right strategy at the right time. As for example, our application can suggest the time when to play hard during a climb, or when to calm-down. Finally, we want to provide to the rider a what-if model of the ride. More specifically, we can simulate a ride by varying the behavior of the rider. What if you had push at this time harder? What if you had ride with a lower average speed? With this model, we can explain simply and practically to the rider the effects of the speed, cadence, hear rate and other parameters to the overall performance.

It is worth to notice that, none of the fitness social network previously mentioned provide such an holistic training approach. Most of them, are excellent records of biometric data showing the past with a catchy dashboard (the time series of the sensors). We want to go further, showing to the rider the present and the future of its success.

Topological Methods for Optimal Transmission Policy for Monitoring Service Based On Swarm of Drones

Proposal submitted by M. A. Pascali (Signals and Images Laboratory) and P. Cassarà (Wireless Networks Laboratory).

The rapid pace of technological progress makes it possible to measure and record growing amount of data, which involves the transmission and processing of large data structures. This is the case of new monitoring services based on swarms of drones. These services allow acquiring an increasing variety of information for environmental and structural monitoring, and in aerial reconnaissance in case of natural disasters. All these services involve different kind of sensors such as chemical, inertial, and optical images, arranged in a wireless network infrastructure.

The aim of this work is to address open problems in these kind of monitoring services. These services require a continuous monitoring of the target area but at the same time they need to limit the amount of transmitted data not to drain the hardware resources of drones. All these requirements open several issues in the field of information science; our specific focus is on the question: how to optimize (minimize) the amount of transmissions toward a ground control station, preserving the data information. For these reasons, we are interested to study an optimized data transmission policy, for drones, which preserves the hardware resources guaranteeing a given level quality of information. In this perspective our idea is to investigate about the recent advances in applied algebraic topology, which provide powerful tools for the efficient analysis and description of big data and complex data structures. Exploiting these topological techniques we want provide a useful description of the data acquired by drones. Consequently, we aim at using this information to develop a novel and efficient policy for data transmission in a collaborative sensing setting.

Problem Statement As stated above, first we will provide a topological description of the data acquired by drones, then, on the basis of this description, we will develop a novel and efficient policy for data transmission. Such a policy has to take into account two main constraints: monitoring service needs a continuous flow of data, and each drone has limited hardware resources (batteries, bandwidth, computational). The ways to save hardware resources providing continuous monitoring are: limiting the number of transmissions, or limit the amount of data to be transmitted. The first option cannot be applied due to the continuous monitoring; on the contrary, the second one seems to be practicable. In this case, the drones must be able to choose which subset of samples of acquired data can be transmitted, without loss of information. Another possibility is given by data transmission at the lowest data sampling possible, and when an event of interest is detected the resolution can be increased only in those drones involved by event. Transmission scenarios, such as those just described, can be addressed providing a topological description of the acquired data through innovative algebraic tools, i.e., the Persistent Homology, defining a mapping between the topological features (invariants) and information features (Entropy, Mutual Information), and finally developing an optimized transmission policy based on the topological invariants of data, for a collaborative sensing setting that is led by a central system, i.e., the ground control station.

A novel approach The novelty of this work relies on optimizing transmission policy through the analysis of the topological invariants of data, in a collaborative sensing setting. Topological invariants are used to reveal the information features linked to data. Also, we need to define a mapping between the topological invariants and the information features. Another aspect of novelty that we can take into account in the definition of our algorithm is its computational complexity, which has to be the lowest possible. The state-of-the-art algorithms, such as those based on Compressive Sensing [54, 55, 56] and Discrete Wavelet Transform [57], consist of sophisticated matrix-vector multiplication and encoding. Due to this complexity, these methods drain the hardware resources. Moreover, these techniques perform their algorithms on the single data source. Our objective is to optimize the information of the data carried out by sources simultaneously.

Topology is a branch of mathematics dealing with qualitative information. "Qualitative" means that topology ignores the quantitative values of the distance used, it does not depend on the chosen coordinates, but rather on the intrinsic geometric properties of an object, such as its shape; while clustering, graphs, networks inform about local properties of data (connectivity, density, etc.). In particular, the homology [58] informs us about global properties of an object, i.e., the i-dimensional holes in the data (number of connected components in dim 0, enclosed voids in dim 2, etc.), especially in presence of noise. Application scenarios, which could benefit from a topological perspective, include shape and texture analysis, protein analysis, complex networks, spatial data and time series, data clustering. The recent burst of interest about topological representation of data is due to the definition of the Persistent Homology (PH) of a growing complex, a sort of generalization of hierarchical clustering for higher order topological features, which provides a visual summary, diagrams or barcodes, of homology groups across all scales. Its success is due both to the publication of a fast algorithm for its computation [59], and to the effort devoted by several researchers in its efficient implementation. Thanks to the increasing popularity of the PH, we find in literature useful examples related to our application, such as [60] about time series analysis and [61, 62] about natural image statistics. Despite the large number of applications found in literature, topological analysis based on PH has not yet been used to characterize and optimize the transmission policy. Our challenge is to rethink this cutting-edge approach to services based on swarms of drones.

Using Persistent Homology Let's assume that M drones independently acquire N samples of the same information, they need to transmit these data toward a ground control station. An efficient way to transmit the data is to identify which and how many samples can be sent by each source, so that the original information can be reconstructed. We assume to represent the sampled data by a matrix with M column and N rows, and to group the rows of the matrix by blocks of size d. Then, we can define a graph where the M[N/d] blocks are its vertices, and the edges can be defined through the cross-correlation among blocks: an edge exists between two vertexes (blocks) if the cross-correlation between them is greater than a threshold. Note that the so defined graph can be weighted and either oriented or not. Such a graph is a suitable object from which to grow a simplicial complex, which can be investigated through the Persistent Homology. Once our data are encoded in a simplicial complex, along with a way to grow it as a nested sequence of subcomplexes (e.g., on the basis of cross-correlation among blocks), the PH is computed and shown via the associated barcodes [63]. A barcode, in a given dimension n, is a collection of horizontal bars in a plane (the horizontal axis corresponds to the parameter growing the complex, while the vertical axis represents an arbitrary ordering of homology generators in dim n). The length of each bar is interpreted as the lifespan or persistence of the corresponding generator. Short bars are interpreted as noise, while long bars as important topological features. Also two barcodes may be compared efficiently using proper distances, such as the Bottleneck distance. This formalization will enable us to highlight hidden information features (e.g., Entropy or Mutual Information) as persistent topological properties of the signal space. Finally, use this information to choose the optimal size d of each block, and to modify the sampling rate of data to be transmitted to the ground control station, preserving the information.

Conclusion In our project we aim at defining a new policy for the transmission of data acquired by drones, based on the topology of the signal space. The steps of the proposed approach are:

a. Defining the signal space as a topological space

b. Computing topological invariants associated to such a space

c. Mapping the topological invariants to information features

d. Validating on data acquired by swarm of drones.

We strongly believe that the problem of signal compression is worth to be investigated from a topological viewpoint, and we expect to define an efficient transmission policy for data acquired by drones in a distributed manner, with low-cost hardware, and not loosing in quality information with respect to other systems endowed with high-cost hardware.

UTOPIA: Understanding the patterns of Abstract Human Mobility with Persistent Homology and Big Data analytics

Proposal submitted by L. Pappalardo (Knowledge Discovery and Data Mining Laboratory) and A. Villa (Signals and Images Laboratory).

Goal Recent studies on human mobility revealed precise patterns underlying the movements of individuals on a physical space. This technical report is written in order to fix the basis for the study of the patterns of abstract human mobility, i.e., how people move among a set of objects in an abstract space (e.g., the Web, songs in the space of musical genres). First, we apply a novel methodology based on Topological Data Analysis to analyze movements in an abstract space and model abstract human mobility dynamics. Second, as case studies we plan to conduct massive experiments on several Big Data sources, each describing an abstract or physical mobility space: Web browsing data, Music Listening data, Purchase Behavior data, GPS and mobile phone traces. Finally, we will use the topological signatures emerging from the analysis in order to represent data into a relevant geometric space and for comparing the patterns emerging from the analysis of abstract mobility with those characterizing physical mobility: Are abstract movements and physical movements regulated by the same fundamental laws?

Targeted breakthrough and long term vision The availability of Big Data describing human movements, such as GPS tracks and mobile phone data, has offered a series of novel studies on the quantitative patterns characterizing physical human mobility, i.e., how people move on the territory. All these studies document the existence of specific patterns in physical human mobility, where a stunning heterogeneity of human travel patterns coexists with a high degree of predictability: individuals exhibit a broad spectrum of mobility ranges while repeating daily schedules dictated by routine [64].

Our project proposal goes beyond physical human mobility and we propose to study the patterns of abstract human mobility, i.e., how people "move" among a set of objects in an abstract space. An example of abstract space is the Web: individuals follow links on Web pages and move from one Web page to another creating browsing trajectories, i.e., sequences of Web domains describing an individual's browsing behaviour. Purchase behaviour, where an individual moves among the space of products in a supermarket, is another interesting example of abstract moving behaviour. An intriguing open question is whether the patterns of abstract human mobility are comparable to the patterns of physical human mobility. Are movements in abstract spaces as heterogeneous and predictable as movements in the physical space? Do the patterns of physical human mobility apply to abstract human mobility, and vice versa? Understanding the mobility patterns of individuals in abstract contexts is of great importance from both a scientific and commercial point of view. From a scientific point of view, it allows to understand the cognitive limits in human movement and their degree of similarity with the physical limits of movement. From a commercial point of view, the abstract mobility patterns can be used to predict in an accurate manner the future behaviour of individuals, e.g., the Web domains they will visit or the music artists they will listen to, and hence for forecasting and recommendation purposes.

The contribution of our approach is twofold. First, we propose to develop a novel methodology based on Topological Data Analysis (TDA) and Persistent Homology (PH) to study individuals' movements in abstract mobility spaces. PH is a powerful tool to study the topological properties of objects mapped on a multidimensional geometric shape. The idea of our methodology is the following: we use TDA to map individuals' abstract trajectories defined as the sequence of visited objects (e.g., the Web browsing history) to an adhoc geometric object called simplicial complex, then we use PH to extract a topological signature of the simplicial complex in order to analyze abstract movements and unveil abstract human mobility patterns. Second, we plan to apply the developed methodology on several case studies, performing massive experiments on Big Data sources describing several physical and abstract mobility spaces: Web browsing, Music Listening, Purchase behaviour, GPS traces from private vehicles and Mobile Phone traces. Using the obtained barcodes we can project the data to an appropriate geometric space. Finally, we compare patterns of physical and abstract human mobility in order to understand deeply the difference between individuals' cognitive mobility limits and physical mobility limits.

Novelty and foundational character Studies from different disciplines on physical human mobility document a stunning heterogeneity of human characteristic traveled distances, and at the same time observe a high degree of predictability in human movements [64]. Recently the patterns of human mobility have been used to build generative models of individual human mobility and human migration flows [65], to construct methods for profiling individuals according to their mobility patterns [64], and to predict the kind of activity associated to individuals' trips on the only basis of the observed displacements [66]. There are widely accepted mobility models and measures, e.g., mobility radius [64], mobility entropy [67], individual mobility networks and origin-destination matrices [66], that can be used to study different aspects of both individual and collective mobility. While physical human mobility has received a lot of attention from the scientific community, there is little work on the understanding of abstract human mobility. At the best of our knowledge there is only one work that studies abstract human mobility through physical mobility metrics. In this work [68] the authors map the Web pages visited by individuals into a bi-dimensional space, then applying standard mobility measures to study the mobility patterns of browsing behavior. Their results are encouraging since they find very similar patterns between physical mobility and Web browsing behaviour.

The ideas coming from computational topology, such as TDA and PH, have been developed in order to visualize and explore high dimensional and complex real-world data. The main advantage of TDA and PH is that they provide a general framework to analyze complex data in a manner that is insensitive to the particular metric and robust to noise. Introduced in the context of data analysis by [69, 70], TDA and PH are used in biology [71], brain functional networks [72], shape recognition [73], sensor network coverage [74] and complex networks [75]. It is only recently that TDA and PH have been used to study different aspects of human mobility. For example a recent application of TDA to physical human mobility [76] unveils that mobile phone users exhibit some robust clustering patterns that correlate with basic socio-economic variables. However, the characterization of movements, visitation patterns, and behavioral habits in abstract spaces is an aspect that has not been addressed yet in literature.

Our project creates a link between human mobility analysis and computational topology. Despite their ability to represent in an efficient way high dimensional data spaces, TDA and PH have not been applied yet to study visitation patterns and movements in abstract spaces. We intend to fill this gap by providing: (*i*) a novel methodology to map a set of data points describing into an abstract space using TDA; (*ii*) a description of homological features (e.g., connected components, cycles, etc.) extracted from the simplicial complex via PH analysis; (*iii*) an analysis of abstract mobility in several contexts by using different Big Data sources and the powerful analytical tools of Data Mining.

Implementation The implementation of our project splits into two main phases. The first phase consists in developing a methodology to map a set of data points describing an abstract space into a multidimensional geometric shape, and splits in the following steps:

1. Mapping a set of data points to a family of simplicial complexes (geometric shapes) indexed by a proximity parameter. In this step we will explore several techniques such as Vietoris-Rips complex, Witness complex, Čech complex (fig.9), graph induced complex, and develop our own techniques.

2. Characterizing the topological properties of the resulting simplicial complexes. The characterization of the obtained simplicial complexes is fundamental to highlight the differences between different abstract spaces. To this purpose we will explore the fast techniques for PH proposed in [77] and integrate it with the so-called "Discrete Morse Theory" (adapted to work with $\mathbb{Z}_2$ coefficients) in order to improve computational efficiency.

3. Deriving from the topological features of the simplicial complexes a set of features describing the mobility behavior of individuals in the abstract space. In this step we will also explore a different projection of data points into a geometric shape by using the mathematical tool called "barcode" [69]: a barcode obtained via PH is a descriptor of both topological and geometric properties of a given simplicial complex and provide useful information that can be exploited to map the original data points into a more proper geometric shape.

The second phase of the project consists in the application of the developed methodology to specific sets of data points, each describing an abstract or physical space. We will perform experiments on the following Big Data sources available at KDD-lab of ISTI-CNR by using Big Data analytics tools such as a distributed processing platform like Hadoop:

- **Web browsing behaviour:** more than 5M anonymized Web browsing history entries corresponding to visits to 187,680 hosts by 524 users between September 21, 2010 to May 24, 2014.
- **Purchase behaviour:** this dataset stores all the purchases at COOP supermarket made by 100,000 individuals during 8 years (from 2007 to 2014).
- **Music Listening behaviour:** the history of listenings of 100,000 individuals on the LastFM online music platforms during two years.
- **Mobile phone traces:** 6 month of Call Detail Records data produced by 1 million users in a large European country.

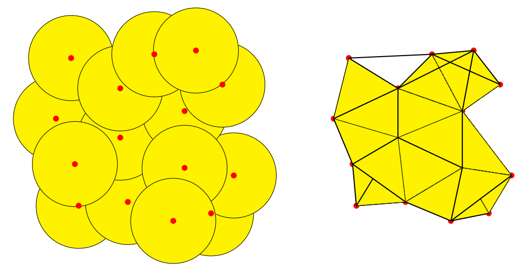

Figure 9. From point cloud to a Čech complex: given different $n+1$ vertices $x_0,\ldots,x_n$, an $n-$simplex σ is added between them if the intersection of the corresponding balls $B_{x_0}\cap\ldots\cap B_{x_n}\neq\emptyset$ is not empty.

- **GPS traces:** 1 month of GPS traces from 150,000 private vehicles traveling in Tuscany during one month (May 2011).

We use the topological features extracted from geometric shapes inferred from these data sets to analyze the pattern of abstract human mobility, by using techniques from mobility data mining and network science. Finally, we describe how abstract mobility patterns change from context to context and compare abstract mobility patterns with the patterns of physical human mobility.

5. Conclusion

This brief report documented the 2016 edition of the ProgettISTI Young Research Award, one of the initiatives promoted by the Istituto di Scienza e Tecnologie dell'Informazione to support the young members of its staff. ProgettISTI was oriented to provide support for innovative, original and multidisciplinary projects of high quality and potential. The choice of theme and the design of the research were entirely up to the applicants yet (*i*) the theme must fall under the ISTI research topics, (*ii*) the proposers of each project must be of diverse laboratories of the Institute and must contribute different expertise to the project idea, and (*iii*) project proposals should have a duration of 12 months. ProgettISTI 2016 edition were characterised by ten project proposals and the following three were awarded: "The Machine-Training – A data-driven personal trainer for cyclists", "EMPATHY: A sensorized doll for assessment and validation of non-pharmacological dementia care", and "Learning from Sequential Visual Data, a Deep Learning Hybrid Approach".

ProgettISTI goes in tandem with the ISTI Young Research Award (YRA) [1, 2] and ISTI Grants for Young Mobility (GYM). All these initiatives were funded through self-taxation of all research laboratories of the Institute thus demonstrating the willingness to incentivise the activity and growth of young researchers. In fact the initiatives will be likely in place in 2017 also.

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Author contributions

Contributions to the paper are described using the taxonomy described in [78]. Writing the initial draft: LC with contributions from project proponents. Critical review, commentary or revision: LC.

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