D8.8.1 REPORT ON THE IQMULUS PROCESSING CONTEST – YEAR 1

Deliverable D8.8.1

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Liguria	Regione Liguria, Genova, Italy

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EXECUTIVE SUMMARY

The deliverable D8.8.1 is related to the IQmulus Task 8.5, described as follows in the Description of Work (DoW):

Focus of the task will be the dissemination of IQmulus results on data processing by means of setting up and running yearly conests, open to the whole scientific community as well as user groups, on research issues which are relevant to the WP4 area of work. Such benchmarking and contests have been widely used in the multimedia domain (e.g., TRECVID, IMAGECLEF), and recently in the 3D retrieval area (SHREC) as a key means to highlight and recognize significant advances in research and ensure reproducibility of results.

This report describes the first year's activity of the IQmulus processing contest, the selection of the most interesting tasks/services proposed as contest tracks, and the list of participants in the proposed challenges. In addition, we list the panel of experts, selected among the partners and involving scientists outside the consortium that have been chosen to support the planning of the contest, establish the processing tasks to be benchmarked and select the appropriate data set, performance measures and procedures to realize the validation.

[1] Integers correspond to submitted versions

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1 INTRODUCTION

Enabling reproduction and evaluation of an algorithm outcome is an acute issue in computer science that rapidly grows with the increase of the demand for efficient and computable solutions in many fields. In this context, the creation of standard datasets with a ground truth and a "quality label" paves the road to a fair evaluation of the existing technologies and the identification of new directions of research.

The IQmulus processing contest will complement and cooperate with the existing benchmarking activities within its sphere of operation so that opportunities and technical gaps can be identified. It is a specific goal of the IQmulus contest to become a reference for the 3D point cloud processing, proposing examples from the Maritime Spatial Planning and the Land Applications for Rapid Response and Territorial Management scenarios. Indeed, IQmulus will combine in the same contest 3D point clouds, generated by Lidar sensors and/or stereovision and will answer to the increasing demand of standard benchmarks in geospatial data processing and foster the combination of heterogeneous data.

The results of the contests will be made publicly available and in particular are planned to be equipped with executable code so as to make the participation in the contests more attractive for scientists. The partners involved in WP4 on Processing Services are expected to participate in the contest with the submission of the algorithms and methods developed in the project, in respect of the IPR rules and restrictions as identified in the Consortium Agreement.

This report describes the first year's activity of the IQmulus processing contest, the selection of the most interesting tasks/services proposed as contest tracks and the list of participants in the proposed challenges. In addition, we list the panel of experts, selected among the partners and involving scientists outside the consortium that have been chosen to support the planning of the contest, establish the processing tasks to be benchmarked and select the appropriate dataset, performance measures and procedures to realize the validation.

1.1 RELATED BENCHMARKS AND EVENTS

A tremendous outbreak of similar benchmarking actions and contests has been noticed for the last five years in many areas of computer science: they are a key means to highlight and recognize significant advances in research and ensure reproducibility of results. For instance, benchmarks have been widely used in the multimedia domain (e.g., TRECVID (Smeaton et al., 2006, Smeaton et al., 2009, Over et al., 2012), IMAGECLEF (Mueller et al., 2010), in multi-view stereo (Strecha et al., 2008) or in image-based object detection (Everingham et al., 2010). More recently, they have been adopted in the area of 3D retrieval (SHREC (Veltkamp et al., 2006)) and keypoint detection (Tombari et al., 2013), in vision for image sequence analysis and autonomous navigation (Geiger et al., 2012, Goyette et al., 2012, Geiger et al., 2013), and in the computer graphics community for surface reconstruction from point clouds (Berger et al., 2013).

An initiative similar to the IQmulus processing contest has started in 2011 under the aegis of the ISPRS (Rottensteiner et al., 2012). The need of new standard test sites that exploit the availability of modern airborne sensors led to the creation of a benchmark on urban object extraction. In particular, both airborne topographic Lidar data and multi-view stereo imagery are provided to compare and evaluate research algorithms for building detection, tree detection and building reconstruction in urban areas. In addition, a benchmark dataset on shape registration has been recently proposed in the field of robotic research (Pomerleau et al., 2013).

The results of the contest highlighted that there is still place for further developments in all the scenarios considered; in particular the detection of small building structures and trees and the production of high-quality level-of-detail building models. As a further outcome, the methods currently at the state of the art do not seem to be able to fully exploit the accuracy potential inherent in the sensor data.

A recent development is also the increase of popularity of Open Source libraries. Well-known examples are Point Cloud Library (PCL), GDAL, CGAL and OpenCV, but the full list is much longer and ranges from professional well-maintained to short-lived, poorly documented code. This poses a new challenge for researchers and software developers: to what extent is it possible, in terms of performance, to embed code from Open Source libraries in a new project. To at least partly answer this question, some functionalities of these Open Source libraries are going to be tested within the framework of the IQmulus processing contest as well.

1.2 ADVISORY BOARD

To allow a large scientific consensus, the IQmulus contest is implemented in collaboration with the research community and the support of an international advisory board, composed of high level scientific and technical experts in the field.

For the first year, the members of the IQmulus consortium involved in the Advisory Board are:

- Silvia Biasotti, CNR-IMATI-GE
- Jan Boehm, UCL
- Clément Mallet, IGN
- Roderik Lindenbergh, TUDelft

The members of the Advisory Board that are external to the IQmulus project are:

- Hamish Carr, Visualization and Virtual Reality Group, University of Leeds, UK;
- Debra Laefer, School of Civil, Structural & Environmental Engineering, University College Dublin, Ireland. Debra Laefer is the recipient of the European ERC Starting Grant "RETURN: Rethinking Tunnelling in Urban Neighbourhoods", 2013-2017.

2 TIMELINE OF THE CONTEST

In the following, we briefly summarize the different steps of the preparation of the first year IQmulus contest.

Jan 2013: Creation of the mailing list of contacts for the contest

May 2013: Start of the activity: discussions of the actions to be carried out the first year, challenges to be met, analysis of the existing datasets and comparison with other benchmarks, analysis of the possible ground-truth, identification of the most promising tracks (in terms of participation and possible ground-truth)

30 June 2013: Joint submission of the IQmulus contest to the ISPRS workshop Laser Scanning 2013

July 2013: Identification of the tracks to be implemented in the first year's contest, namely registration and feature extraction of drainage basins

7 Aug 2013: Circulation of the first call for participation

20 Sep 2013: Circulation of the second call for participation

Oct 2013: The contest is running and the results are analysed and evaluated

Nov 2013: The results will be presented at the ISPRS workshop Laser Scanning 2013, 11-13 November 2013, Antalya, Turkey

3 THE CONTEST INFRASTRUCTURE

The contest is organized on an existing computational platform hosted by CNR-IMATI-GE. Such a platform is distinct from the overall IQmulus infrastructure and is a CPU-cluster unit related to the Visualisation Virtual Services (VVS) offered by the FP7-INFRASTRUCTURES project VISIONAIR (2011-2015), for the preparation of virtual scenes and experiments for any graphical and Virtual Reality settings. The VVS is conceived as an operational and web-based resource repository, which involves the integration of a Shape Repository, a Tool Repository and an Ontology and Metadata Repository, together with an advanced Search Framework. The outcome of the contest, being evaluated on an infrastructure independent of the IQmulus one, will be used to estimate the gain that is obtained by running the services on the IQmulus infrastructure itself.

To host the IQmulus Processing contest, the VVS is upgraded augmenting its data storage and processing capabilities. The services for running the benchmarking and evaluation procedures are implemented using the Collage Authoring Workbench, http://collage.ge.imati.cnr.it, developed by Academic Computer Center Cyfronet AGH in Cracow in Poland, which allows the documentation and the long-term preservation of the outcome of the contests.

3.1 THE COLLAGE AUTHORING WORKBENCH

The Collage Authoring Environment is a framework for collaborative preparation and publication of so-called computational experiments that can back executable papers. The environment enables researchers to seamlessly embed chunks of executable code and data into scientific publications in the form of Collage items, and to facilitate repeated execution of such codes on underlying computing and data storage resources. Using the Collage Authoring Workbench scientists can develop executable papers and generate items that can be embedded into a web site. The Collage team piloted the Collage Environment for a Special Issue of Computers & Graphics, published in May 2013. Elsevier published this Special Issue of Computers & Graphics on ScienceDirect and integrated computational elements created by authors using Collage into the on-line article. For more information and links to the articles please see www.elsevier.com/executablepaper.

The Collage Authoring Environment was originally developed in support of research teams linked to the PL-Grid project. It is based on the GridSpace2 platform that was targeted at an unrestricted range of communities. GridSpace2 was designed and is still developed by the Distributed Computing Environments Team, a part of Academic Computer Center Cyfronet AGH in Cracow, Poland. The Collage Authoring Environment, along with a publishing server prototype, won first prize in the Executable Paper Grand Challenge organized as part of the International Conference on Computational Science 2011 in Singapore (Ciepiela et al., 2013, Ciepiela et al., 2012, Nowakowski et al., 2011).

Figure 1 shows a screenshot of the initial page the participants find when connecting to the contest infrastructure. The infrastructure is accessible via https protocol at the web address http://collage.ge.imati.cnr.it/workbench and a tutorial with examples on its usage are available at http://collage.ge.imati.cnr.it/tutorials.

Currently, the operating system used in the Collage Authoring Workbench adopted in the IQmulus Processing Contest is Linux Ubuntu 12.04.

There, the participants may run their code and executables using the classic Unix bash shell (http://www.hypexr.org/bash_tutorial.php#emacs), the Windows files .exe can be run using the environment "wine" (http://www.winehq.org/) and the interpreted language Octave 3.2.1 (http://www.gnu.org/software/octave/) is available to run MATLAB-like code. Also plots are possible using the gnuplot package (http://www.gnuplot.info/). To support geospatial data processing, additional libraries, such as PCL, GDAL, MPI, VDK, FLANN, Boost, etc., are available and already installed in the VVS infrastructure.

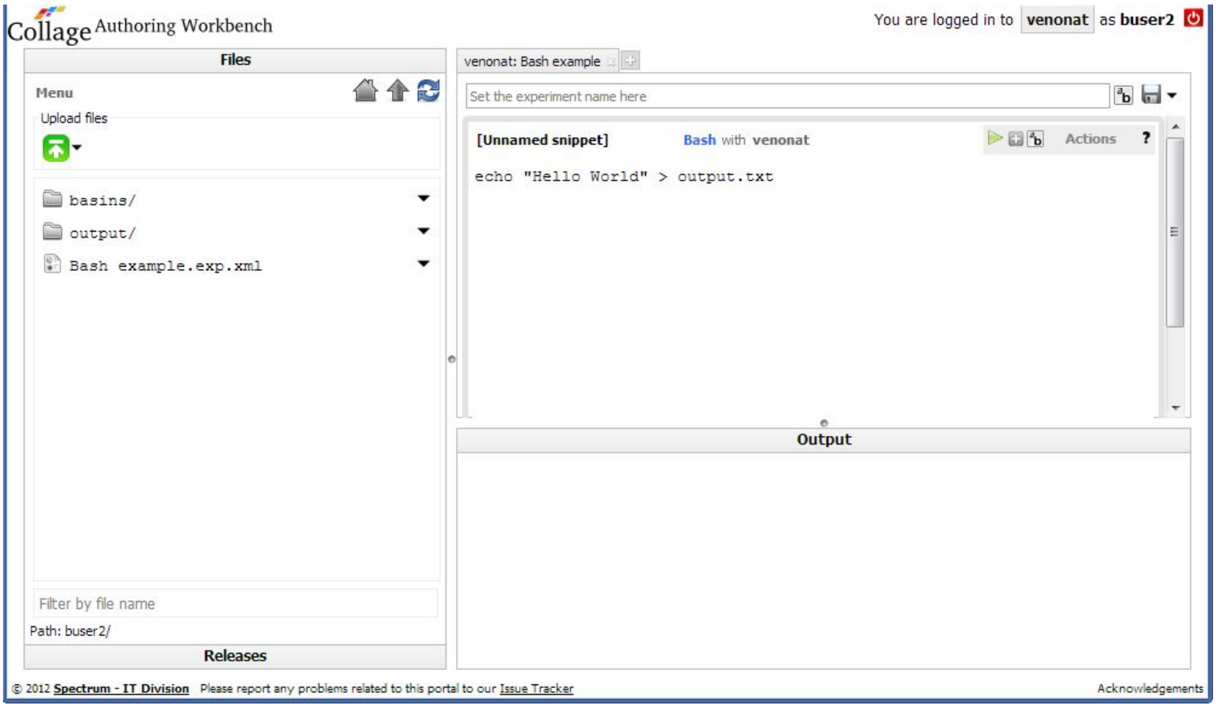

FIGURE 1 A SCREENSHOT OF THE MAIN PAGE OF THE COLLAGE AUTHORING WORKBENCH

4 THE FIRST YEAR'S TRACKS

The contest enables reproducible evaluation through the creation of standardized benchmarks and evaluation methodologies. In the first year, two challenges have been identified as acute issues in geospatial data: i) the registration of sets of point clouds and ii) feature extraction (in particular the extraction of drainage basins from a DEM).

In the following, we describe the two sets of tests proposed in the contest, distinguishing them according to the challenge proposed.

4.1 REGISTRATION OF POINT CLOUDS

Six datasets have been selected to evaluate the properties of the methods and are provided to the participants. The datasets are made available in the folder “Registration” in the home page of each participant on the Collage Authoring Workbench. The datasets answer to problems that arise in data registration, for instance the registration of point clouds acquired in two different epochs (for instance the Amiens_AirborneLidar dataset); the registration of crowded urban streets acquired with a mobile vehicle (for instance the datasets Paris1_MMS and Paris3_MMS); the registration of different airborne Lidar (for instance the datasets originating from Regione Liguria data).

Datasets provided by IGN (four):

Amiens_AirborneLidar: The dataset has been acquired over a dense urban area (city center with low-rise buildings, Amiens, France) at two different dates, and with distinct airborne Lidar scanners, resulting in two different ground patterns, Figure 1. The first acquisition was completed in 2003 (point density of 7.5 pts/m^2, 400,000 pts), with a Toposys fiber scanner. Spatial sampling is therefore very inhomogeneous (1.5 m between two fibers, and 0.15 m between two measurements of the same fiber). The second acquisition occurred in 2008 (point density of 2 pts/m^2, 90,000 pts, oscillating mirror) with an Optech 3100 EA device (Gressin et al., 2013).

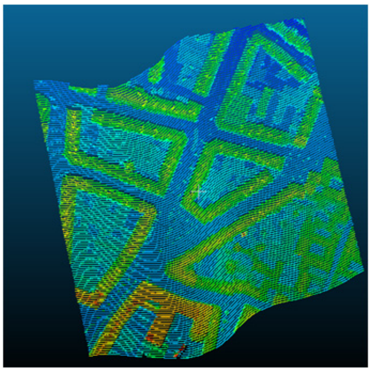
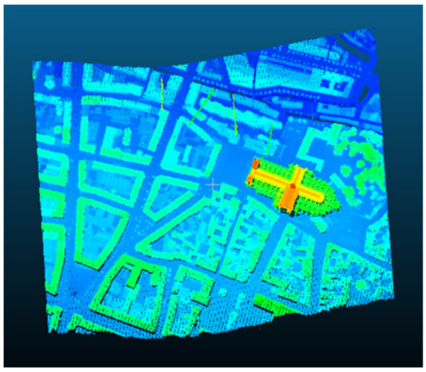

FIGURE 2 TWO DISTINCT AIRBORNE LIDAR SCANS OF THE URBAN AREA OF AMIENS, FRANCE. LEFT: MOBILE MODEL, RIGHT: REFERENCE MODEL. COLOURS REPRESENT THE Z-VALUES.

Paris1_MMS This dataset is acquired with the Stereopolis vehicle, (Monnier et al., 2013, Paparoditis et al., 2012). The positional system is coupling two GPS and one Applanix IMU POSVL200. The GPS acquire position at 1Hz, while the IMU has a frequency rate of 100Hz. This IMU has a drift of 3 deg/hr, resulting in an accuracy of about 20 cm for a GPS signal loss of 1 minute (2 m for 3 minutes). Street in Paris, same challenges as for Paris3_MMS, see Figures 3 and 5.

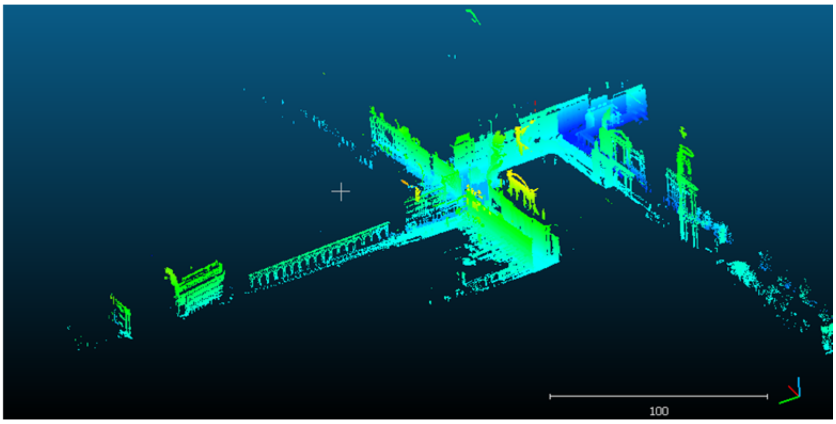

FIGURE 3 ONE OF THE TWO POINT CLOUDS OF THE PARIS1_MMS DATASET. THE COLOURS CORRESPOND TO THE Z-VALUES

Paris2_MMS These point clouds are acquired with the Stereopolis vehicle, (Gressin et al., 2013, Paparoditis et al., 2012). This dataset covers one building facade in an urban area in Paris, France. The mobile mapping system acquired the same area twice on the same day but with a time shift of one hour. A RIEGL LMS-Q120i lidar has been used for that purpose, and oriented towards the roof top (pavement and road surfaces omitted). The challenges here are: (1) not exactly the same parts of the buildings are sampled and (2) a 3D shift between both point clouds naturally exists, due to the georeferencing process. The point cloud density is very variable, even within the same point cloud, depending on the angle of incidence of the variable distance between objects and the MMS. However, the typical density on the facades of the buildings is near 100 pts/m^2 (around 200,000 pts per point cloud), see Figure 4.

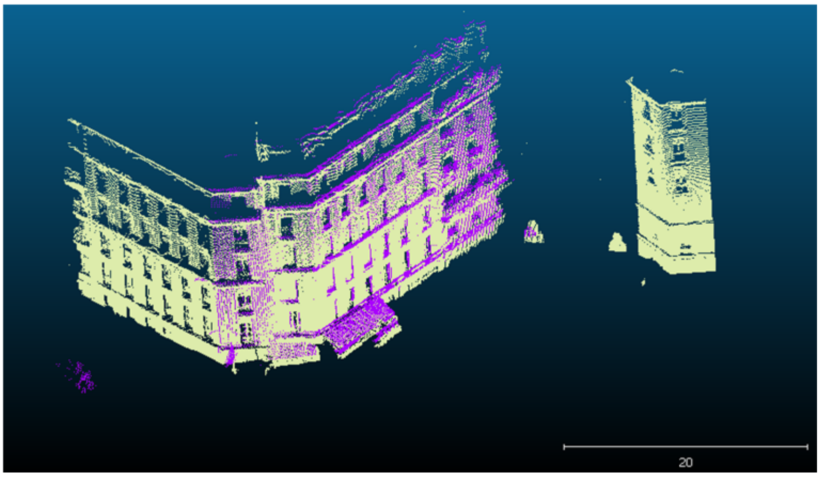

FIGURE 4 PICTURE WITH THE TWO POINT CLOUDS OF THE PARIS2_MMS DATASET. ONE COLOUR FOR EACH DATASET

Paris3_MMS: This dataset was acquired with the Stereopolis vehicle, (Gressin et al., 2012, Paparoditis et al., 2012). This dataset covers a surface of 0.5 km^2, with a trajectory of 1.5km along several streets. The whole point cloud includes 5 million points. The acquisition procedure of this dataset is based on a RIEGL LMS-Q120i lidar sensor, which provides vertical profiles perpendicular to the platform trajectory. Positioned vertically, the lidar sensor allows acquiring the roads, the sidewalks and medium-sized buildings. However, the tops of the highest buildings may not be visible, depending on the distance from the sensor to the building. This configuration allows to cover areas with several

interesting objects (street furniture), but also included many moving objects such as pedestrian or cars (Figure 5).

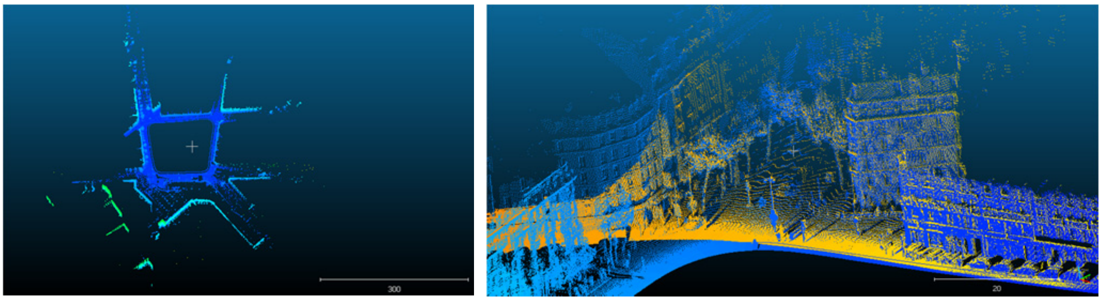

FIGURE 5 TWO VIEWS OF THE PARIS3_MMS DATASET. LEFT: TOP VIEW, Z-COLORED; RIGHT: OBLIQUE VIEW, GPS-TIME COLORED.

Datasets originating from airborne Lidar scans of Regione Liguria (two):

These datasets are created from Airborne Lidar scans provided by Regione Liguria and owned by the Italian *Ministero dell'Ambiente*. To make these datasets suitable for a data registration challenge, the data have been randomly perturbed with Gaussian noise and rotated with different rotations (varying from 0.25 rad to 0.9 rad). In addition, the original regular grid (1-meter scan) has been non-uniformly filtered using a random filter.

Vernazza: this dataset is made of three point clouds, in .ply ASCII format, originating from the same acquisition (sample 23 in the sample datasets of the IQmulus project). This dataset presents both urban characteristics (buildings and streets) and countryside ones (hills with terracing-like shape), thus showing a high shape variability (Figure 6, right).

Genova: this dataset is made of four point clouds, in .ply ASCII format, originating from two different acquisitions of the urban center of the city of Genova (Figure 6, left).

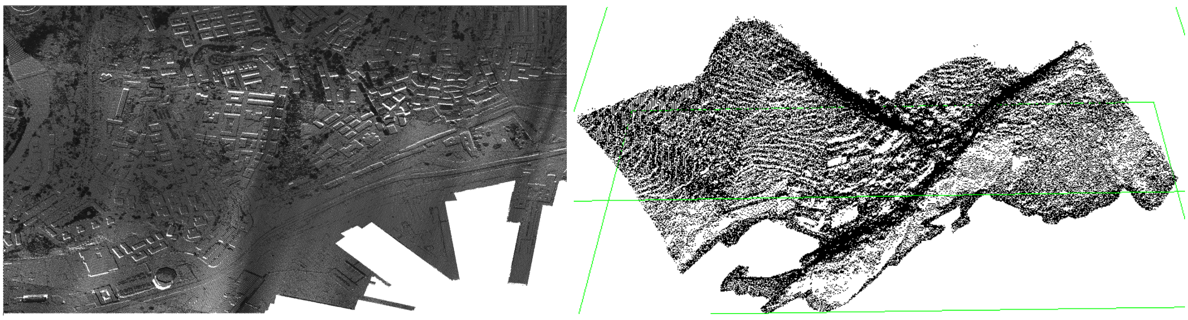

FIGURE 6 LEFT: THE REFERENCE DATASET OF THE CITY OF GENOVA, RIGHT: ONE OF THE POINT CLOUDS OF THE VERNAZZA DATASET

4.2 FEATURE EXTRACTION (DRAINAGE BASINS FROM A DEM)

Three datasets are proposed for the track on the extraction of drainage basins. The three models come from the DEM of the Liguria area, as provided by Regione Liguria. The DEM models are in geotiff format and correspond to a sampling of the area with a pass of 5 metres. The algorithms in the literature for the extraction of medium-large drainage basins (more than 10mq) perform very well and reliably. The challenge posed by these datasets is the selection of medium/small drainage basins.

The choice of the three areas (Savona-Albissola, Portofino and its surroundings, Cinqueterre and La Spezia gulf) corresponds to two specific challenges:

1. The selection of small drainage basins (less than 10mq, approximatively around 4-5 mq) is still an open problem and needs the validation on real cases;
2. The identification of small zones hydrogeologically unstable but with a large impact on the context: the large variability of the shape of these areas makes them very risky when a large amount of rain falls in a short time. For instance, the Cinqueterre area was subject to a dramatic flash flood that damaged a large part of this area. In addition, two of these areas have a large environmental importance: Portofino and Cinqueterra are both natural parks of national relevance.

The pictures of the three sites are shown in Figure 7. The intensity of the grey level represents the z-value.

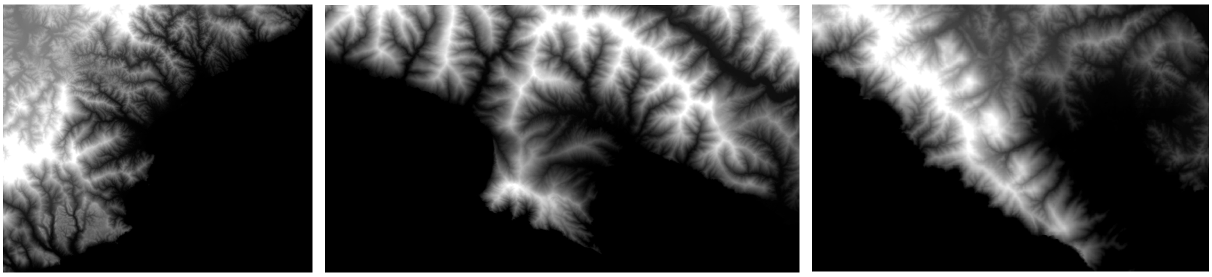

FIGURE 7 THE THREE DATASETS SELECTED FOR THE EXTRACTION OF THE DRAINAGE BASINS

5 PARTICIPANTS OF THE CONTEST

In this section we list the participants of the contest tracks, with a brief description of the techniques used to participate in the track.

5.1 REGISTRATION OF POINT CLOUDS

Six participants have been registered for this track, three of them are members of the consortium and three are external participants. Namely:

1. IGN, ICP variant
2. TUDelft, feature-based registration
3. UCL, feature-based registration
4. Francois Pomerleau, Autonomous Systems Lab, ETH Zürich, using an ICP variant
5. Martin Isenburg, RapidLasso, using the LAStools library
6. Zhizhong Kang, China University of Geosciences, Beijing City, China.

5.2 FEATURE EXTRACTION (DRAINAGE BASINS FROM A DEM)

Three participants have been registered for this track; all of them are members of the IQmulus consortium, namely:

1. B. Sirmacek, Dept. of Geoscience & Remote Sensing, TUDelft.

2. S. Pittaluga, CNR-IMATI-GE (with two different algoritms: the TauDEM module http://hydrology.usu.edu/taudem/taudem5/index.html and the GRASS one http://grasswiki.osgeo.org/wiki/Hydrological_Sciences)
3. V. Phan Hien, Dept. of Geoscience & Remote Sensing, TUDelft with the ArcHydro module http://blogs.esri.com/esri/arcgis/2011/10/12/arc-hydro-tools-version-2-0-are-now-available/

6 EVALUATION METHODOLOGY

6.1 REGISTRATION OF POINT CLOUDS

The ground-truth for all the point clouds chosen for this track is well known.

For the datasets with real misalignments, the ground-truth consists of the transformation matrix obtained via the manual alignment of the two point clouds from the best solution retrieved for the automatic algorithm developed for that purpose (Gressin et al., 2013).

For the two datasets derived from Airborne Lidar scans of the areas of Genova and Vernazza, the exact transformation matrix from the original dataset and the perturbed one is known by the construction of the dataset. The original dataset with the record of the correspondences in the perturbed one is also known; therefore, we know which point of one dataset corresponds to which point in the other one and the rotation/translation/perturbation applied.

Evaluation criteria. The evaluation of the performance of the methods proposed is both qualitative and quantitave. As quantitative criteria we consider the time expired and the memory occupied by each run. The qualitative measures aim at evaluating the quality of the registration in terms of the mean and standard deviation of the distances of the registered points to their correspondences in the ground-truth point cloud; and, when available, in terms of the difference between the transformation model detected by the method and the ground-truth one.

6.2 FEATURE EXTRACTION (DRAINAGE BASINS FROM A DEM)

The ground-truth is the official map of the drainage basins owned by Regione Liguria. Such a map is validated by experts and currently taken as the reliable map of the drainage basins of the Regione Liguria. To evaluate the methods proposed, a subset of significant features (e.g., drainage basins and breaklines that are significant from the geospatial point of view) have been identified and the final score will depend on the correct identification of these characteristics.

To validate the methods participating in the track we consider qualitative and quantitative parameters like in the registration track. Similarly to the registration track, we compute time and memory storage as two quantitative indices, while the quality of the results is obtained by superposing the official drainage map with the outputs of the methods and counting the elements that correspond in the two maps, the deviation of the two maps in terms of differences of the areas of the basins and deviation of the flow lines.

7 FUTURE PLANS

The set up and the yearly run of open contests are crucial for the dissemination of the IQmulus results on data processing to the whole scientific community and user groups. Besides the presentation of the IQmulus contest during the ISPRS Workshop Laser Scanning 2013, November 11-13, 2013, we plan to propose the presentation of the contest to other conferences in the field.

Thanks to the feedback received from the members of the Advisory Board and the participants of the tracks of the first IQmulus contest, new challenges are planned for the next editions of the contest, among others we list:

- Reconstruction from Lidar airborne scans (for instance, D. Laefer will make available the Lidar scans of the center of Dublin obtained in the ERC grant RETURN);
- Feature detection: extraction of significant shape characteristics;
- Change detection, which is an acute issue in geospatial data and related to the task 4.5 of the IQmulus project.

Moreover, for the next years we plan to strengthen the link with the panels of experts leaving the coordination of some tracks to members of the Advisory Board. In addition, we plan to increase the number of members of the Advisory Board.

Finally, we plan to submit the results of the contests for publication in internationally recognized journals. Among others we are currently considering journals in the remote sensing area:

- ISPRS Journal of Photogrammetry and Remote Sensing, http://www.journals.elsevier.com/isprs-journal-of-photogrammetry-and-remote-sensing/
- Remote sensing, http://www.mdpi.com/journal/remotesensing (open access)
- Computers and Geosciences, http://www.journals.elsevier.com/computers-and-geosciences/
- IEEE Transactions on Geocience and Remote Sensing http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=36

In addition, we are exploring the organization of special issues of journals with executable code, following the example of the “Elsevier executable paper” based on the Collage Authoring Workbench published in 2013 by the Computers & Graphics journal.

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