Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

ICSC
Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

HaMMon: Data acquisition and digital twin creation

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Spoke 3 General Meeting, Elba 5-9 / 05, 2024

Scientific Rationale

HaMMon (Hazard Mapping and vulnerability Monitoring)

The project aims at extending the current knowledge in hazard mapping, monitoring and forecasting from industrial perspectives by means of innovative technologies, for the Italian territory

The activities involve intensive use of scientific visualization and artificial intelligence technologies, especially for assessing and extracting meaningful information on risk-exposed assets

WP 2: Post-event Natural Disasters

Post-event analysis activity is often complicated or even impossible to access on-site. Extreme natural phenomena (floods, landslides, earthquakes, etc.) often prevent physical access to the affected areas.

Objective:

- Improve damage assessment, claims processing and time needed for on-site inspections after a natural disaster
- Development of algorithms to identify and classify objects and features within 3D models and 2D images
- Collecting requirements of a web tool for the remote inspection of areas damaged by natural disasters
- Enabling analysis of areas affected by extreme natural events that would otherwise not be possible

Technical Objectives, Methodologies and Solutions

T2.1: Workflow for data acquisition and creation of digital twin

Development of a workflow to produce a high-resolution 3D tiled model (in the order of centimeters), by means of the "Aerial Structure-from-Motion" approach

Employment of Unmanned Aerial Vehicles (UAVs) for high-resolution topography reconstruction. Enabling the exploration of specific features or environments from multiple perspectives and at various scales. We want to provide rich user experiences by realizing exploration scenarios that may not even be achievable in the actual field in a real-world scenario

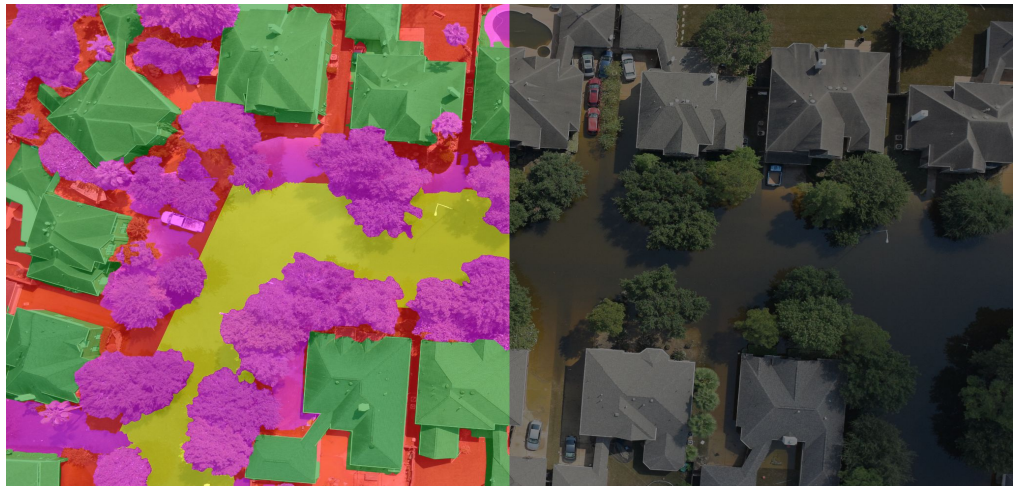
Creation of digital twin using dedicated Structure from Motion photogrammetry software, as Agisoft Metashape, which involves identifying matching features in different 2D images captured along proper UAV flight paths, combining them to create a sparse and dense point cloud, building a mesh, and applying a texture. Python scripts have been implemented to automate the entire workflow

Metashape

Technical Objectives, Methodologies and Solutions

T2.4: Automatic (or semi-automatic) analysis

Development and deploying of appropriate machine learning model to identify and classify different types of buildings within a 3D model



Dataset: FloodNet 2021

Survey of the Flooded Area

Segmentation of aerial images and information transfer to the digital twin

Tiramisù

The model, described in the paper "The One Hundred Layers Tiramisu," is a fully convolutional neural network, therefore adaptable to various input image sizes. It utilizes dense blocks for enhanced feature detection and is structured like a U-net to be able to address segmentation tasks. This model has been successfully used for segmenting radio astronomical images

Technical Objectives, Methodologies and Solutions

Links Tiramisù:

"*Fully Convolutional Networks for Semantic Segmentation*" arXiv:1411.4038v2

"*Densely Connected Convolutional Networks*" arXiv:1608.06993v5

"*U-Net: Convolutional Networks for Biomedical Image Segmentation*" arXiv:1505.04597v1

"*The One Hundred Layers Tiramisu: Fully Convolutional DenseNets for Semantic Segmentation*" arXiv:1611.09326v3

"*Radio astronomical images object detection and segmentation: A benchmark on deep learning methods*" arXiv:2303.04506v2

Links SAM (Segment Anything Model):

"*An Image is Worth 16x16 Words: Transformers For Image Recognition At Scale*" arXiv:2010.11929v2

"*Segment Anything*" arXiv:2304.02643v1

Timescale, Milestones and KPIs

M7 [September 2023 – February 2024]

- **TAR 2.1 — Produce draft algorithm for creation of digital twin from UAV**

  Development of a draft of the workflow to produce a high-resolution 3D tiled model with centimeter accuracy. The workflow will utilize the "Aerial Structure-from-Motion" (ASfM) approach (e.g., Westoby et al., 2012), which involves identifying matching features in different 2D images captured along proper UAV flight paths, combining them to create a sparse and dense point cloud, creating a mesh, and generating a texture.

- **KPI 2.1 –** Code on GitHub repo https://github.com/VisIVOLab/UAV-digital-twin

  Reference on Open Access Repository: Algorithm for creation of digital twin from UAV https://www.openaccessrepository.it/record/143691

Timescale, Milestones and KPIs

M8 [March 2024 - June 2024]

- **TAR 2.2 — Produce an algorithm for UAV data acquisition and creation of digital twin**

  Final release of the workflow to produce a high-resolution 3D tiled model. Dividing the process into individual steps for easier project management and control. Evaluate the most effective structure to fully utilize the available computational resources

- **KPI 2.2 –** Updated code on GitHub repo https://github.com/VisIVOLab/UAV-digital-twin

- **M9 - M10**
  Creation of a digital twin on a real use case with the support of ENEA in the city of Faenza. One of the worst-hit towns by the floods in mid-May 2023. Damage caused by the flooding of the Lamone river. The waters had caused the collapse of the embankment on which the protective structures were resting, with the flooding of the neighboring area

Accomplished Work, Results: data acquisition and data process

UAV field activity

UAV photo acquisition (1)
- defined altitude
- frequency rate
- photos overlap 90%
- reduce images distortion

Referencing of the environment (2)
- GCPs establishment
- reduce doming effect
- scale point cloud
- georeference point cloud

Image quality test (3)
- disable low-quality images (< 0.6 value)
- improve the accuracy of the final model

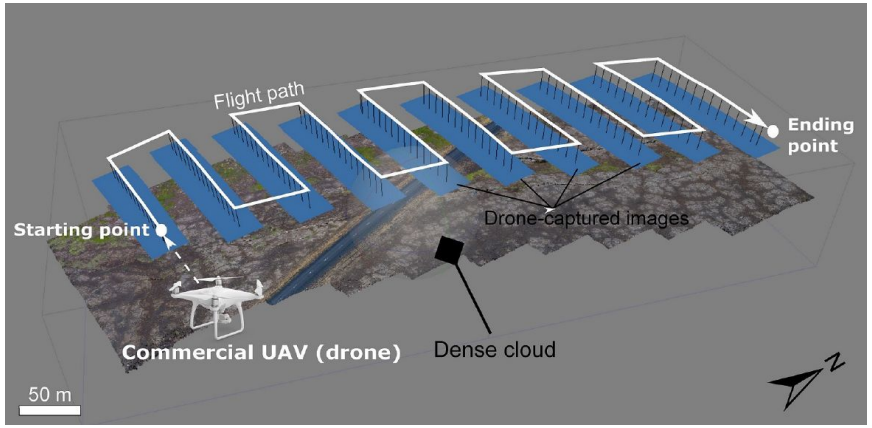
Sparse and Dense Point Cloud calculation (4)
- estimate camera locations and orientations
- Depth Map filtering

Mesh and Texture model (5)
- high number of faces
- export texture file

3D Tiled model creation (6)
- use of Levels of Detail to manage model resolution
- export tiled model

SfM processing

Image: Immersive Virtual Reality for Earth Sciences DOI: 10.15439/2018F139



Survey Bonali Fabio: Fleri Sicilia 2018

Accomplished Work, Results: computing resources

- **INAF OACT Resources:**

  Intel(R) Xeon(R) CPU E5-2650 40 core, RAM 126GB, GPU Tesla K40c,
  1 TB storage

- **WP1 @ Cluster Kubernetes HaMMon:**

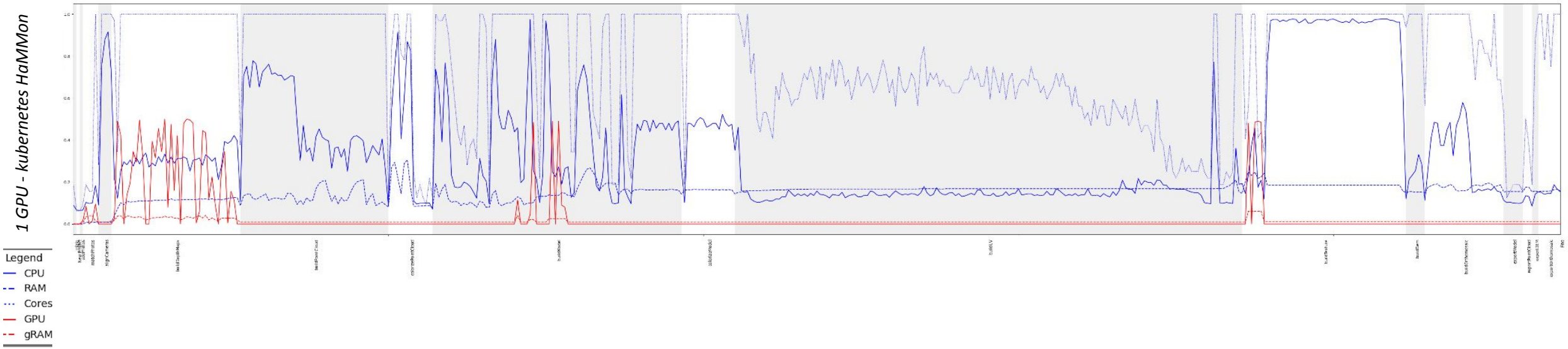
  CPU 32 core, RAM 64GB, 2 GPUs **(WP2 T2.1 Agisoft Metashape)**
  CPU 32 core, RAM 125GB, GPU **(WP2 T2.4 Machine Learning)**
  CPU 32 core, RAM 125GB, GPU **(WP4 Machine Learning)**
  CPU 32 core, RAM 125GB, GPU **(WP4 Machine Learning)**

- **Spoke 2 @ ICSC Resources:**

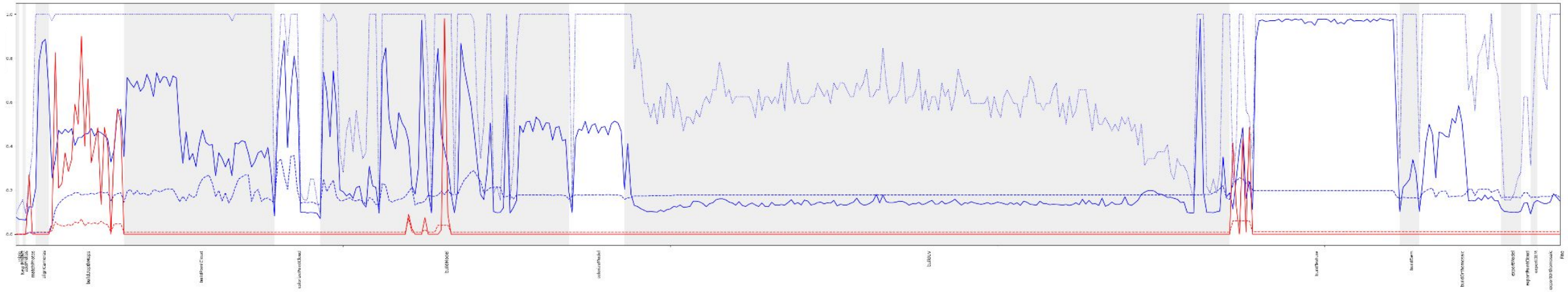
  100.000 core-hours on the CINECA/Leonardo Booster, 30 TB storage at CINECA, 50 core on the INFN Cloud , 10 TB storage at INFN

Accomplished Work, Results: benchmark profiling

1 GPU - kubernetes HaMMon



2 GPU - kubernetes HaMMon



Accomplished Work, Results: benchmark profiling

cluster kubernetes HaMMon: 1 GPU

Modulo	CPU	Cores	RAM	GPU	gRAM	Mean	Interval (seconds)
New Project	0.066000	0.062500	0.000000	0.000000	0.000000	0.025700	0.000000
addPhotos	0.065000	0.062500	0.000000	0.000000	0.000000	0.025500	0.000000
alignCameras	0.661250	0.820312	0.008290	0.000000	0.009705	0.299911	16.224074
buildDem	0.239500	0.989583	0.152332	0.000000	0.010742	0.278431	28.547048
buildDepthMaps	0.314024	0.983232	0.108884	0.246341	0.028855	0.336267	225.338968
buildModel	0.380658	0.810918	0.143963	0.022722	0.011594	0.273971	446.017311
buildOrthomosaic	0.314400	0.905000	0.177492	0.000000	0.010742	0.281527	139.080624
buildPointCloud	0.487660	0.986702	0.132929	0.000000	0.009705	0.323399	262.409155
buildTexture	0.846404	0.945312	0.189797	0.037308	0.015546	0.406873	297.616113
buildUV	0.154186	0.602679	0.167071	0.000000	0.009705	0.186728	914.399848
colorizeModel	0.445706	0.952206	0.162024	0.000000	0.009705	0.313928	92.599756
colorizePointCloud	0.399643	0.540179	0.163953	0.000000	0.009705	0.222696	74.969925
exportDEM	0.113500	0.531250	0.155440	0.000000	0.010742	0.162187	5.667298
exportModel	0.102667	0.229167	0.154231	0.000000	0.010742	0.099361	28.233991
exportOrthomosaic	0.155714	0.933036	0.158401	0.000000	0.010742	0.251579	34.246353
exportPointCloud	0.123000	0.343750	0.167876	0.000000	0.010742	0.129074	11.372910
matchPhotos	0.110000	0.318750	0.006839	0.042000	0.026556	0.100829	21.571915
Total	0.344710	0.772595	0.152903	0.029693	0.012549	0.262490	2701.044280

1 Tesla V100: MIN_RAM_USED: 0.0 MB MAX_RAM_USED: 3.586 GB
RAM: *MIN_RAM_USED*: 2.19 GB *MAX_RAM_USED*: 20.7 GB

cluster kubernetes HaMMon: 2 GPUs

Modulo	CPU	Cores	RAM	GPU	gRAM	Mean	Interval (sec)
New Project	0.067000	0.125000	0.000000	0.000000	0.000000	0.038400	0.00
addPhotos	0.066000	0.156250	0.000000	0.000000	0.000000	0.044450	0.00
alignCameras	0.687000	1.000000	0.008282	0.000000	0.009705	0.340997	16.18
buildDem	0.235167	0.890625	0.165459	0.000000	0.011002	0.260450	28.42
buildDepthMaps	0.450652	0.998641	0.162031	0.396087	0.043340	0.410150	126.57
buildModel	0.390303	0.797286	0.183570	0.016842	0.012358	0.280072	433.45
buildOrthomosaic	0.314000	0.885000	0.189855	0.000000	0.011002	0.279971	138.76
buildPointCloud	0.481391	0.999321	0.193919	0.000000	0.009705	0.336867	260.57
buildTexture	0.848019	0.943510	0.202560	0.028365	0.016779	0.407847	296.85
buildUV	0.150297	0.592736	0.178759	0.000000	0.009705	0.186299	1052.57
colorizeModel	0.442235	0.948529	0.177019	0.000000	0.009705	0.315498	92.64
colorizePointCloud	0.384000	0.560268	0.217761	0.000000	0.009705	0.234347	75.60
exportDEM	0.117500	0.500000	0.168219	0.000000	0.011002	0.159344	5.88
exportModel	0.103833	0.229167	0.167529	0.000000	0.011002	0.102306	28.33
exportOrthomosaic	0.154143	0.910714	0.172286	0.000000	0.011002	0.249629	34.47
exportPointCloud	0.129667	0.510417	0.181159	0.000000	0.011002	0.166449	11.65
matchPhotos	0.104667	0.239583	0.004486	0.090000	0.006612	0.089070	10.74
Total	0.342448	0.752775	0.180345	0.025655	0.012600	0.262765	2716.01

2 Tesla V100: *MIN_RAM_USED*: 0.0 MB *MAX_RAM_USED*: 4.613 GB
RAM: *MIN_RAM_USED*: 2.13 GB *MAX_RAM_USED*: 23.8 GB

Next Steps and Expected Results

- **Parallel and Distributed Task Management in Metashape Server**
  Test multiple instances of Metashape tasks across multiple nodes. This involves optimize distribution of workload based on the unique characteristics of each node to ensure efficient task execution

- **Integration of Digital Twin and Machine Learning**
  We are considering whether to continue training on direct images obtained from UAVs or to integrate 3D digital twin more closely on machine learning
  (not outstanding results with Metashape and CloudCompare)

- **Model to assess the extent of flooded and damaged homes**
  This will include the ability to distinguish between homes with and without damage and estimate the damage entity (Φ-Net ImageNet Challenge)

- **Evaluation SAM (Segment Anything Model)**
  The Segment Anything Model (SAM), developed by Meta's FAIR (Fundamental AI Research), is a complex model inspired by recent developments in Natural Language Processing. Interesting where the training dataset is limited