This study was carried out within the RETURN Extended Partnership and received funding from the European Union Next-GenerationEU (National Recovery and Resilience Plan – NRRP, Mission 4, Component 2, Investment 1.3 – D.D. 1243 2/8/2022, PE0000005) – SPOKE TS2.

*Geo*spatial *AI* for monitoring and risk analysis in critical infrastructures

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OBJECTIVES OF RETURN PROJECT

The main objectives of the extended **RETURN** partnership are:

1. **Enhancing** the understanding of environmental and climatic risks.
2. **Improving** the prediction and management of risks.
3. **Developing** new technologies for environmental monitoring.
4. **Promoting** efficient data utilization.
5. **Strengthening** the linkage between research and end products.

multi-Risk sciEnce for resilienT commUnities undeR a changiNg climate

Spoke 6 TS2 - Multi Risk Resilience of Critical Infrastructures

T 6.4.2- AI and deep learning systems for intelligent unsupervised surveys

Geospatial AI for monitoring and risk analysis in critical infrastructures

OBJECTIVES OF THE RESEARCH

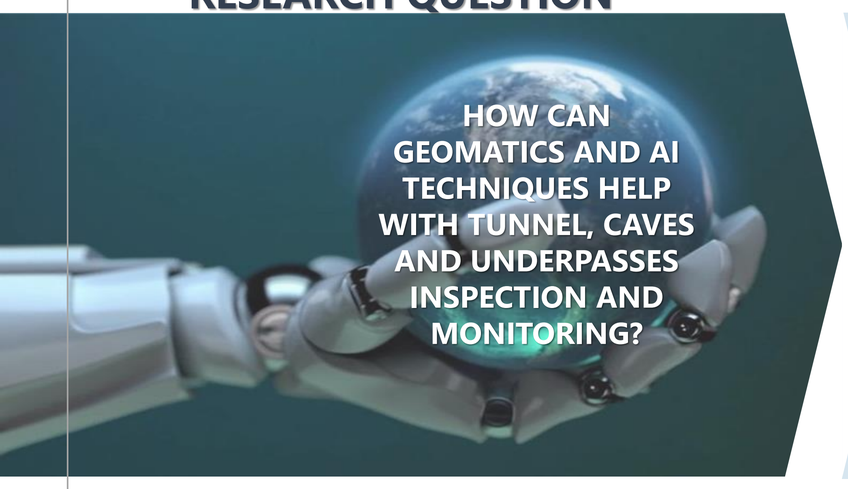
Investigate the application of AI to data collected with several sensors with the purpose to perform:

1. **autonomous surveys** collaboration with PIC4SeR
2. **critical infrastructures** inspections.

According to the EU:
CRITICAL INFRASTRUCTURE is an asset or system which is essential for the maintenance of vital societal functions.
The damage to a critical infrastructure […] may have a significant negative impact for the security of the EU and the well-being of its citizens.

TUNNEL, CAVES and UNDERPASSES

RESEARCH QUESTION



METHODOLOGY

1. **Collect data** using conventional and non-conventional systems, even adopting unmanned systems (rovers, drones) equipped with different types of sensors.
2. **Calibration, data fusion, and data processing** (images, points cloud, 3D models) supported by AI/ML/DL/RL techniques.
3. **Data post-processing** uses AI, combining innovative solutions for classification, segmentation, and damage detection and recognition.
4. **Digital information management** using GIS and BIM platforms to realize digital twins for smart infrastructure management.

CHALLENGES

Surveys and inspections in underground environments can be challenging:

i) limited access, confined spaces, and **poor lighting**;

ii) geometric repetitiveness with very **similar patterns and textures**;

iii) **absence of GNSS signal** and the need to use alternative technologies for positioning;

iv) operational and safety **risks for operators** in case of instability.

GEOMATICS TECHNIQUES

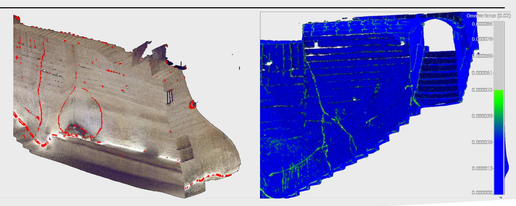
Several 3D surveying techniques were employed, e.g. *Terrestrial Laser Scanner* (TLS) based on the VIS (*Visual Identity System*), SLAM (*Simultaneous Localisation and Mapping*) system and *photogrammetry,* using also 360 digital camera.

FUTURE STEPS

1. Sensor calibration and data integration	
Thermal data	
Multi-, hyper-spectral data	
X-Band SAR Interferometry	

2. Data post-processing	
Damage detection	Crack damage
	Water infiltration
Feature extraction from	Point cloud
	3D model

Examples of crack detection using the omnivariance feature.



3. AI developement	
Point Cloud	PointNet++/PointCNN
LiDAR data	LiDARNet
Images	Texture analysis

CASE STUDIES

Identification of different **CASE STUDIES**, differentiated by the **type of application**, **techniques** and **sensors** used, **geometries**, **construction types**....

pointcloud

images

3D model

AI

Traforo del Monte Bianco
Italy-Franch

It is the 11-kilometer-long tunnel linking Italy and France, from Courmayeur, in the Aosta Valley, to Chamonix. Extraordinary closures are currently in place for work to improve the safety of the infrastructure.

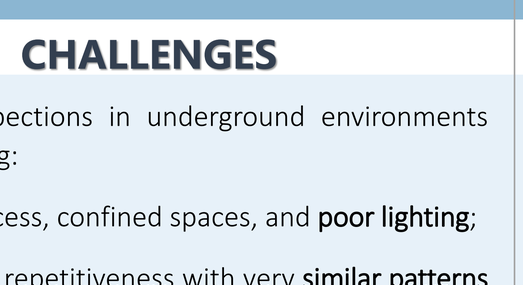
Integrating LiDAR, photogrammetry and thermal analysis to detect **water infiltration** in underground structures for predictive maintenance and infrastructure management.

Gallerie Pietro Micca
Torino Sotterranea

A series of underground tunnels in Turin, famous for their historical role during the siege of Turin in 1706.

Integrating different sensors (LiDAR, cameras, structured light scanners) on the Clearpath UGV Jackal Rover, equipped with depth cameras and lights, for the purposes of testing **autonomous navigation under particularly complex conditions**:
Narrow tunnels, low ceilings, and solid brick linings exhibit linear geometries and repetitive textures.

Sottopasso Lingotto
Torino



One of the main junctions of the city of Turin, built in 1930 was widened to two lanes in 1979. Structural reinforcement and conservative rehabilitation work is currently underway.

Training artificial intelligence algorithms for the detection of deteriorations in reinforced concrete structures, through the **integration of imaging techniques, point clouds, and geophysical data**.

A short video showing the 3D models made!

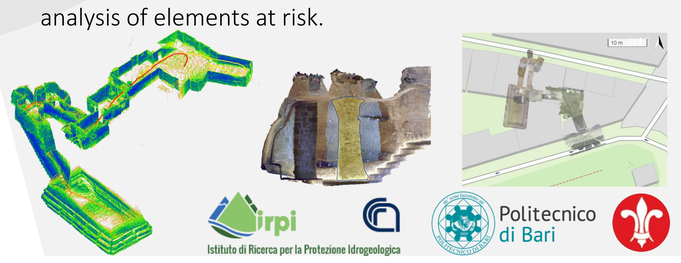
SCAN ME!

Rete di cavità antropiche
Gravina di Puglia

A dense network of underground cavities under squares and streets of the urban center, is partly unexplored.

Metrically corrected three-dimensional models for the purposes of:

- structural **monitoring**, study of subsidence phenomena,
- **analysis and evaluation of** areas at **risk** of collapse,
- volumetric and planimetric analysis of the **interaction between hypogeal and urbanized heritage**,
- **automated fracture detection** for the purpose of stability analysis of elements at risk.



Istituto di Ricerca per la Protezione Idrogeologica

Politecnico di Bari

DURING THESE 8 MONTHS...

Hard/Soft Skills Courses	*Conferences/Workshops*	*Papers/Posters*	*Didactics*	*Activities Team*
Soft Skills: 44/40 hours Hard Skills: 53/100 hours	The 12th International Symposium on Mobile Mapping Technology (MMT 2023) and Mobile Mapping Technology2023 - MOBILE MAPPING SCHOOL 2023, Padova	*Iterative refraction-correction method on MVS-SfM for shallow stream bathymetry.* Lingua, A. M., Maschio, P., Spadaro, A., Vezza, P., and Negro, G. https://doi.org/10.5194/isprs-archives-XLVIII-1-W1-2023-249-2023, 2023	Corso di orientamento - EDILI wanna be: fotogrammetria e droni per il rilevo del patrimonio costruito (Cuneo) - 20 hours	Referente 2023 team Studentesco DIRECT – Disaster and RECovery Team
Ongoing: - Heritage at risk: documentation, assessment, mitigation - 16 hours HS	65° Convegno Nazionale SIFET 2023, Arezzo	*Piattaforme aeree non convenzionali per il rilievo tridimensionale e la rappresentazione multi-scala di ambienti costieri.* A. Spadaro, F. Chiabrando, A. Lingua, P. Maschio, L. Teppati Losè **Vincitore del Premio Miglior Poster 2023, 65° Convegno Nazionale SIFET 2023**	Corso di orientamento - EDILI wanna be: fotogrammetria e droni per il rilevo del patrimonio costruito (Torino) - 15 hours	*"Learning by Doing" Team DIRECT Activities* - 12-16/06/2023, Rilievi Isola di Culuccia, Sardegna
Ongoing: - Tecniche geomatiche innovative per il monitoraggio di strutture, infrastrutture e territorio - 30 hours HS	2GG - Due Giorni di Geomatica 2023 - AUTeC, Arezzo	*Analisi e confronto di tecniche geomatiche SLAM e VIS per l'analisi strutturale e geomeccanica di cavità artificiali in prossimità delle gravine.* A. Spadaro, N. Grasso, M. Piras, D. Giordan, A. Parisi Poster 2023, 65° Convegno Nazionale SIFET 2023	*Ongoing*: - Conoscenza del patrimonio costruito nell'epoca dei cambiamenti climatici - 10 hours - Knowledge of the built heritage in the era of the climate changes- 20 hours	*"Learning by Doing" Team DIRECT Activities* - 04-08/09/2023, Rilievi Grotte di Aisone, Piemonte