ROBOSAT PROJECT

Autonomous robot navigation in the wild using satellite-based 3D geographical information

RCF project no. 368663

D1.2 Ethical Deliverable addressing AI aspects, misuse and dual use

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1. Executive Summary

This ethical deliverable outlines the principles, risks, and mitigation strategies for the ROBOSAT CHIST-ERA project focused on creating a scalable MultiGIS platform for high-quality data collection in unconstrained environments using autonomous quadrupedal robots. The project integrates GNSS and GIS data with multi-modal sensors (cameras, LiDARs, IMUs, GNSS receivers, and I/Q raw data grabbers) to build a comprehensive database for challenging terrains such as the Swiss Alps and Finnish forests.

The ethical framework ensures compliance with EU regulations, including GDPR and Horizon Europe Ethics Guidelines, and addresses key concerns related to privacy, data security, algorithmic fairness, and environmental sustainability. The project also incorporates AI/ML-based tools for data management and labeling, which introduces additional ethical considerations such as transparency and bias mitigation.

Key commitments include:

- Protecting personal and location-sensitive data through anonymization and encryption.
- Ensuring transparency and accountability in data processing and dissemination.
- Implementing robust governance mechanisms.
- The deliverable identifies potential risks—such as privacy breaches, misuse of location data, algorithmic bias, and environmental impact—and proposes comprehensive mitigation strategies. By embedding ethics into every stage of the project, we aim to foster responsible innovation and societal trust while advancing GNSS/GIS technologies for real-world applications.

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2. Introduction

The rapid advancement of satellite-based technologies has enabled the massive collection of multidimensional, three-dimensional Geographic Information Systems (GIS) data. However, correlating such large-scale GIS datasets with local information in unconstrained and unstructured environments—such as mountainous regions or dense forests—remains a significant challenge. Our CHIST-ERA ROBOSAT project addresses this gap by developing a scalable MultiGIS high-quality data collection platform that leverages autonomous robotic systems and advanced sensing technologies.

The core innovation of the project lies in the deployment of a quadrupedal robot capable of performing long-distance missions in challenging environments, including the Swiss Alps and Finnish forests. Equipped with a multi-modal sensor suite—comprising cameras, LiDARs, Inertial Measurement Units (IMUs), Global Navigation Satellite Systems (GNSS), and an I/Q raw data grabber—the robot enables consistent and repeatable collection of local environmental data. This data will be integrated with large-scale GIS datasets to create a comprehensive and high-fidelity representation of complex terrains.

Beyond data collection, the project will develop general-purpose and automated tools for multi-sensor data storage, management, consolidation, and labeling. These processes will be powered by Artificial Intelligence (AI) and Machine Learning (ML) algorithms to ensure scalability and efficiency. Furthermore, the project will explore innovative solutions for effective data dissemination and utilization, promoting open science principles while safeguarding ethical and legal compliance.

The benefits of this approach are twofold. First, the integration of GIS data into GNSS systems will enhance the detection and mitigation of interference phenomena such as multipath, jamming, and spoofing. Second, improved GNSS localization will enable more accurate labeling and fusion of GIS data, creating a virtuous cycle of refinement and reliability. Ultimately, this project aims to lay the foundation for ubiquitous robotic platforms operating in the wild, offering improved GNSS localization services and contributing to the creation of a MultiGIS database for unstructured environments that surpasses existing datasets by an order of magnitude.

The purpose of this ethical deliverable is to ensure that all activities within the project adhere to European Union ethical standards, including Horizon Europe Ethics Guidelines, GDPR, and principles of responsible research and innovation (RRI) [1][2][3]. GNSS and GIS data are inherently sensitive because they involve geolocation and spatial information, which can reveal personal behaviors, movement patterns, and socio-economic indicators. Therefore, ethical considerations are critical to prevent misuse, protect privacy, and maintain societal trust.

3. Ethical Principles and General Framework

The project is guided by the following ethical principles:

- **Respect for Human Dignity and Privacy**
  GNSS and GIS data can indirectly identify individuals or communities. The project commits to anonymization and aggregation techniques to safeguard privacy.
- **Transparency and Accountability**
  All data processing steps will be documented and made available to stakeholders. Decisions regarding data use will be traceable and auditable.

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- **Fairness and Non-Discrimination**
  Algorithms and models developed using GNSS/GIS data will be tested for bias to avoid discriminatory outcomes in applications such as urban planning or resource allocation.
- **Compliance with EU Regulations**
  - **GDPR** for personal data protection.
  - **Horizon Europe Ethics Guidelines** for research integrity.
  - **INSPIRE Directive** for spatial data interoperability.

4. Ethical principles for the robot implementation

The Robosat project involves numerous ethical aspects related to the collection and use of geospatial data, robotic autonomy, and environmental impact. The robot collects detailed information about natural environments, which raises issues of privacy and data protection, requiring the anonymization of sensitive information, compliance with legal regulations, and transparency regarding who uses these data and for what purpose. In Stage 1 of the project, ethical aspects such as autonomy and automated decision-making were detailed, focusing on clarifying responsibilities in case of incidents, the auditability of AI decisions, and the prevention of risky actions that could endanger people, infrastructure, or the environment.

Additionally, the use of AI for automatic data labeling may introduce geographic or ecological biases, making it necessary to include human oversight and train algorithms on diverse datasets to prevent discrimination. Environmental impact is another essential aspect, as the robot may affect wildlife, trails, and ecological balance, requiring environmental studies and respect for natural paths. Furthermore, the ethics of disseminating collected data demand fair use, prevention of abusive or commercial exploitation, and implementation of ethical licenses to ensure responsible and beneficial access for the scientific community. In this stage, the classification of ethical principles was expanded.

Thus, an extended classification of these principles was developed:

1. **Principle of safety and operational robustness:** Any autonomous system navigating uncontrolled natural environments must be designed to minimize risks to people, animals, the environment, and infrastructure.
   • **Physical risk control:** The robot is exposed to varied scenarios—unstable slopes, sliding rocks, snow, areas with precipitation. Navigation and analysis algorithms must be rigorously validated in controlled conditions before operating in real environments.
   • To prevent unintentional disasters, the robot must be equipped with emergency stop mechanisms and clear behavioral limits.
2. **Principle of respect for the natural environment:** Mountains are fragile, and an autonomous robot can cause damage: soil compaction, disturbance of wildlife, alteration of vegetation.
   • **Minimizing ecological footprint:** Both algorithmic and physical design must support movement modes that do not damage the soil: adjusting limb pressure, avoiding sensitive areas (bird habitats, dwarf pine zones, marshes), and sticking to existing trails.
   • **Sensitivity to wildlife:** The robot's vision system can be used not only to detect physical obstacles but also to avoid protected species. The AI must identify the presence of animals (chamois, bears, birds) and retreat or bypass the area rather than "compete" for territory.
   • **Obligation to leave no trace:** Ethically, the robot must not become a source of pollution—batteries, components, mechanical oils must be responsibly managed. If the system malfunctions, the project must include recovery operations so that the robot does not remain abandoned in the landscape.

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3. **Principle of algorithmic transparency:** Although computer vision and navigation algorithms may be complex, it is essential that critical decisions are explainable to the team operating the robot.
   • **Practical explainability:** The robot must be able to justify its choices. Providing only an answer is not sufficient.
   • **Traceability:** Captured data (images, positions, maps) must be recorded so that any incident can be investigated. Traceability is a condition of moral responsibility—otherwise everything becomes a forest of shadows.
   • **Clear communication with operators:** Any unusual terrain change must be reported, and the AI's confidence level in its predictions must be clearly communicated. The human team should not be surprised by the machine's decisions.
4. **Principle of data protection and privacy:** Even in mountain areas, the robot may capture people, private properties, shelters, or intervention vehicles. Visual and geospatial data are sensitive.
   • **Responsible data collection:** The robot must be configured to collect only what is necessary for navigation. There is no ethical justification for storing images of hikers, for example, if they are irrelevant to the mission.
   • **Anonymization and minimization:** If capturing people is unavoidable, the system must apply automatic anonymization (face/silhouette blurring). Data volumes must be limited to project purposes, and data retention must be clearly defined.
   • **Cybersecurity:** Any autonomous AI system represents a vulnerability point. Protecting it from unauthorized access is part of ethics: if someone took control of the robot, they could endanger lives or the environment.
5. **Principle of human control and supervision:** The robot is autonomous, but autonomy does not mean absence of control.
   • **Humans remain in the loop:** Operators must be able to intervene at any time—to modify the route, stop the robot, or limit autonomous capabilities. Ethically, the robot must not become an "independent actor" in nature.
   • **Graduated autonomy:** The level of decision-making delegated to the AI must be calibrated to risk:
   o simple route → high autonomy
   o unstable terrain → reduced autonomy
   o proximity to people/animals → minimal autonomy
   • **Clear responsibility:** It is necessary to explicitly define responsibility in case of an incident:
   o algorithm developers
   o field operators
   o supervision team
   o hardware manufacturer
6. **Principle of fairness and algorithmic impartiality:** At first glance, a mountain robot seems far from social AI dilemmas. However, biases may appear subtly.
   • **Bias in training data:** An obstacle detection model trained on images from sunny days will perform poorly in fog or snow—a form of operational unfairness. Ethics requires diversity in data: seasons, weather conditions, terrain types, soil textures.
   • **Bias in interpreting terrain changes:** If historical maps are incomplete, the robot may erroneously interpret natural variations as dangerous "anomalies." It is important that the algorithm has a realistic threshold for differentiating natural variability from significant degradation.
7. **Principle of responsibility and continuous improvement:** Ethics is not a static document, but a path rewritten along with the robot's evolution.
   • **Audit mechanisms:** Periodic evaluations of AI performance, checks of collected data, and monitoring of environmental impact are mandatory.

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- **Field feedback:** Operators and mountain specialists must participate in evaluations. An autonomous robot becomes more ethical when it listens—indirectly—to those who use and observe it.

Some examples for each principle are listed below:

- **Safety and operational robustness:** The robot detects an unstable boulder on the slope and automatically activates braking and reroutes.
- **Respect for the natural environment:** The robot identifies a ground-nesting bird and changes its path to avoid the nesting area.
- **Algorithmic transparency:** The robot sends the operator the message: "Changing route because sensors detected an unstable slope with a 72% probability of sliding."
- **Data protection and privacy:** The robot captures a group of tourists with its front camera and automatically blurs their faces before saving the image.
- **Human control and supervision:** As the robot approaches a large group of people, the operator can take manual control to reduce the risk of unexpected interaction.
- **Fairness and impartiality:** The algorithm is trained on images captured under very different conditions—snow, dense fog, storm, rain, strong sunlight—to avoid performing well only in sunny weather.
- **Responsibility and continuous improvement:** The technical team analyzes the robot logs monthly and notices it overly avoids gravel areas; they update the algorithm to improve accuracy.

To sum up, Table 1 gives a Summary of adopted ethical principles for robotic and autonomous systems with their brief description and advantages

Table 1. Summary of adopted ethical principles for robotic and autonomous systems with their brief description and advantages

Principle	Description	Advantages
Safety and operational robustness	Reducing risks for humans, animals, and the robot in unstable terrain.	Prevents accidents
Enables efficient control in critical situations	The robot detects an unstable boulder on the slope and activates automatic braking + route change.	
Respect for the natural environment	Protecting fragile ecosystems: soil, vegetation, wildlife.	Reduced ecological impact
Avoiding soil degradation	The robot identifies a bird's nest and changes its route to avoid the sensitive area.	
Algorithmic transparency	The robot's decisions must be explainable and recorded.	Facilitates investigations
Fast diagnosis	The robot sends: "Changing route because the slope has a 72% landslide risk detected by sensors."	
Data protection and privacy	Minimal data collection and image anonymization.	Protects individuals' identity
Strengthens data security	The robot captures tourists and automatically blurs their faces before storage.	
Human control and supervision	Operators can intervene at any time; autonomy is adjusted according to risk.	Avoids erroneous AI decisions
Clarifies responsibility	The operator takes manual control when the robot approaches a large group of people.	
Algorithmic fairness and impartiality	The AI must function correctly in diverse conditions.	Error reduction
Uniform performance	The model is trained with images from snow, fog, storms, strong light — not only for good weather.	

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Responsibility and continuous improvement	Periodic audits and adjustments based on real observations.	Fast problem detection
Field relevance	The team analyses the logs monthly and corrects the algorithm because the robot excessively avoids gravel areas.	

5. Data Management and Privacy

5.1. Data Collection

The project will collect GNSS data from satellite systems (e.g., Galileo, GPS) and GIS data from public repositories and partner organizations. When data involves individuals (e.g., mobility studies), explicit informed consent will be obtained, and participants will be informed about:

- Purpose of data collection.
- Duration of storage.
- Rights to withdraw consent.

5.2. Data Storage and security

- All data will be stored on secure servers within the EU.
- Encryption will be applied both in transit and at rest.
- Access will be role-based, ensuring only authorized personnel can handle sensitive datasets.

5.3. Data sharing

- Open science principles will be followed for non-sensitive datasets.
- Sensitive data will be shared under controlled access agreements.
- Data will be anonymized and aggregated before publication.

6. Risk and mitigation strategies

The integration of GNSS and GIS data in unconstrained environments, combined with autonomous robotic platforms and AI-driven data processing, introduces several ethical and operational risks. These risks are categorized below, along with proposed mitigation measures:

6.1. Potential risks

Several potential risks have been identified and are listed below.

1. **Privacy Breach & data protection risks**: GNSS and GIS data can reveal sensitive location information, potentially identifying individuals or private properties during data collection missions.
2. **Misuse of location data**: GNSS data could be exploited for tracking individuals.
3. **Algorithmic Bias and transparency**: GIS-based models may reinforce socio-economic inequalities; AI/ML algorithms used for data labeling and consolidation may introduce bias, leading to inaccurate or discriminatory outcomes.
4. **Environmental and Sustainability Risks**: High computational demands for data processing and storage may increase energy consumption and carbon footprint (also addressed in Section 6)
5. **Safety & operational risks**: Autonomous robots operating in challenging terrains may pose physical hazards to wildlife or the environment.

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6.2. Mitigation measures

The planned mitigation measures are listed below:

- **Ethical Review Board**: All research protocols involving personal user data will undergo ethical review.
- **Technical Safeguards**: Apply anonymization and aggregation techniques before storing or sharing data; Implement GDPR-compliant consent procedures for any human-related data; Use end-to-end encryption for data transmission and storage.
- **Misuse mitigation**: Restrict access through role-based permissions and secure authentication; maintain trails for all data access and processing activities; share sensitive datasets only under controlled agreements.
- **Bias mitigation**: Conduct bias testing and validation on all AI models; document and publish model training datasets and methodologies for transparency; include human-in-the-loop verification for critical labeling tasks.
- **Other mitigation measures**: Adopt energy-efficient computing practices and green data centers; optimize algorithms for low-power processing; follow local regulations for autonomous systems in natural habitats.

7. Impact on Society and Environment

Both positive and negative impacts have been identified as well as several sustainability issues, described in the next subsections.

7.1. Positive impacts

- Enhanced disaster response through real-time GNSS/GIS data.
- Improved urban planning and traffic optimization.
- Support for environmental sustainability via precise land-use mapping.

7.2. Negative impacts

- There is a risk of privacy erosion if safeguards fail.
- Unequal access to GNSS/GIS technologies, creating digital divides.

By our mitigation methods listed in Section 6.1 we plan to alleviate these negative impacts.

7.3. Sustainability considerations

- GNSS infrastructure consumes energy; the project team will also be aware of energy-efficient data processing.
- Data centers will adopt green computing practices where possible.

8. Ethical Governance and Monitoring

8.1. Roles and Responsibilities

- **Coordinator**: Oversees compliance and reporting.
- **Consortium Partners**: Ensure adherence to ethical guidelines in their tasks.

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- **External Advisory Board**: Provides independent oversight.
- **Local DPOs**: provide help in complying with ethical principles at each unit

8.2. Monitoring mechanisms

- Ethical report submitted to CHIST-ERA and annually revised.
- Incident response plan for data breaches.

9. Conclusions

This deliverable outlines the ethical framework for the project, emphasizing privacy, transparency, fairness, and sustainability. By integrating these principles into all stages of research and development, the project aims to advance GNSS and GIS technologies responsibly, ensuring societal trust and compliance with EU standards.

10. References

[1] European Commission: Horizon Europe Ethics Guidelines
[2] GDPR Regulation (EU) 2016/679
[3] INSPIRE Directive (2007/2/EC).

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