MandEye MR Caver LiDAR System

technology for cave exploration and mapping

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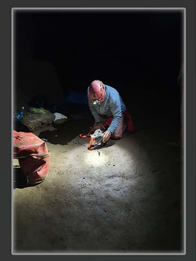
Context & Objectives

LiDAR (Light Detection and Ranging) technology uses laser beams, measuring the return time of the laser pulse to generate highly accurate 3D models.

In speleology, this technology provides major advantages over classical mapping methods:

- fast data acquisition;
- high accuracy, including micro-details;
- possibility to document hard-to-reach areas.

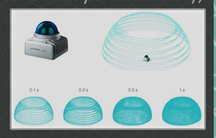


Equipment

MandEye MR (Mission Recorder) Caver is a speleology-adapted version of the MandEye system, an open-source and open-hardware project. The equipment, consisting of two LiDAR sensors and a computer, is carried on the shoulder, allowing continuous scanning while moving through the cave.

Key specifications:

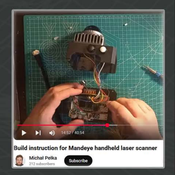
- Scanning range: up to ~40 m (data captured beyond 70 m+);
- Accuracy: ± 2–3 mm;
- Weight: < 1 kg;
- Autonomy: up to 5 hours (depending on batteries used);
- Speed: > 100,000 points/second.

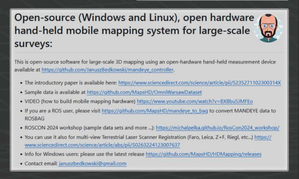


About the Developers

MandEye is an open-source and open-hardware project initiated by J*anusz Będkowski* (Polish Academy of Sciences), with hardware design by ***Michał Pełka***. The hardware is published on GitHub (https://github.com/JanuszBedkowski/mandeye_controller), and the HD Mapping processing and mapping software is available at MapsHD (https://github.com/MapsHD/HDMapping).

The version we use, **MandEye MR Caver**, integrates the Livox **Mid-360 LiDAR** and was developed and adapted specifically for speleological applications.





Open-source (Windows and Linux), open hardware hand-held mobile mapping system for large-scale surveys:

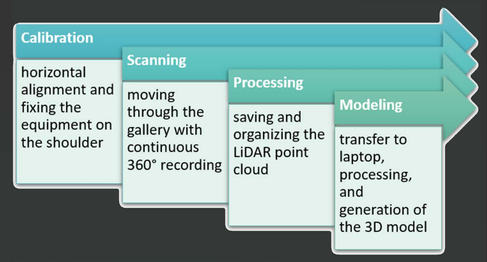
This is open-source software for large-scale 3D mapping using an open-hardware hand-held measurement device available at https://github.com/JanuszBedkowski/mandeye_controller

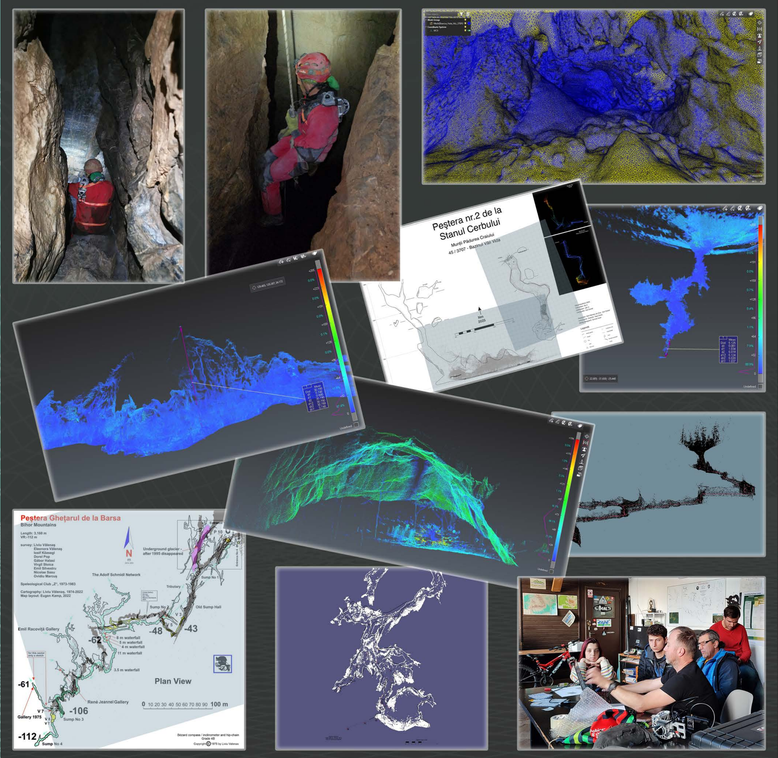
- The introductory paper is available here: https://www.sciencedirect.com/science/article/pii/S2352711023003144
- Sample data is available at https://github.com/MapsHD/OmniWarsawDataset
- VIDEO (how to build mobile mapping hardware) https://www.youtube.com/watch?v=-BXBBuGJMEo
- If you are a ROS user, please visit https://github.com/MapsHD/mandeye_to_bag to convert MANDEYE data to ROSBAG
- ROSCON 2024 workshop (sample data sets and more ...) https://michalpelka.github.io/RosCon2024_workshop/
- You can use it also for multi-view Terrestrial Laser Scanner Registration (Faro, Leica, Z+F, Riegl, etc..) https://www.sciencedirect.com/science/article/abs/pii/S0263224123007637
- Info for Windows users: please use the latest release https://github.com/MapsHD/HDMapping/releases
- Contact email: januszbedkowski@gmail.com

Methodology

The **MandEye MR Caver** system enables mobile scanning, carried on the shoulder. Data is collected while walking or during rope descents/ascents, without stopping exploration.

Workflow

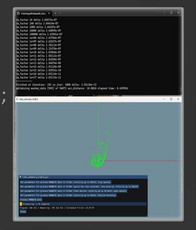




Software

Data processing is carried out with dedicated open-source applications:

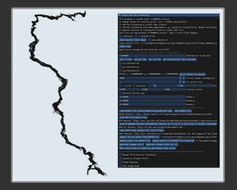
- **MandEye Controller** – raw data collection and management;
- **HD Mapping** – advanced point cloud processing and trajectory reconstruction;
- **CloudCompare** – alignment, filtering, and 3D visualization;
- **QGIS/ArcGIS** (or other BIM / GIS software) – spatial integration and cartographic representations.

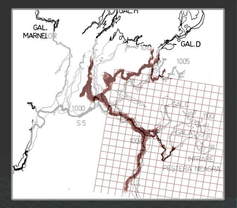


The result is a detailed 3D digital model of the cave, usable both for documentation and for interdisciplinary analysis.

Results

Using the **MandEye MR Caver** system enables the generation of detailed 3D reconstructions of underground galleries and chambers, volumetric data, cross-sections useful for measurements and analyses, as well as complete 3D models that accurately reproduce cave geometry. In addition, comparisons with classical surveying methods highlight differences in accuracy, coverage, and duration, demonstrating the superiority of LiDAR technology.





Advantages

- High (millimetric) accuracy and full coverage;
- Fast data acquisition, directly while moving;
- Portability – system under 1 kg, shoulder-mounted;
- Reusable digital documentation for: cave exploration, scientific research, underground archaeology, cave conservation and management;
- Interdisciplinary integration.

Limitations

- Limited autonomy (~5 hours of continuous operation);
- Requires post-processing on powerful computers capable of handling large datasets;
- Relatively high costs compared to classical methods;
- System under continuous development (open-source), which may limit technical support.

Conclusions

The **MandEye MR Caver** system enables fast and accurate cave documentation, both while walking and during vertical traverses, generating detailed 3D models that can be used in exploration, research, conservation, and underground archaeology.

The technology represents a qualitative leap over classical surveying methods, providing high accuracy and full coverage, but it requires powerful computers to process large data volumes, as well as relatively high financial investment.

Acknowledgements

We thank the developers of the **MandEye** system for their openness in making an open-source and open-hardware project available, for their support in acquiring the equipment, as well as for their constant collaboration and willingness to adapt the software based on experience gained directly in the field, under speleological exploration conditions.

We also thank ***Tomasz Pawłowski*** for his availability and patience in introducing us to the use of the equipment and data processing software.

Last but not least, we thank the sponsors, partners, and friends who supported the acquisition of the device and its use in speleological exploration and documentation: ***Victor Ursu***, www.speologie.org, ***Petre Lupșea***, ***Liviu Guiaș***, as well as all those who, through their contributions, made it possible to implement this technology in our activities.