The event, the Nordic Workshop on 3D Cave Modelling, was arranged by the speleological societies in Finland, Iceland and Sweden and hosted by the Finnish speleological society. It didn’t only attracted participants from the Nordic countries, but also from several European and Latin American countries – a total of 35 participants showed up! There were five presentations on photogrammetry and LiDAR (including the use of iPhone 12 Pro), but there was also plenty of time for discussion and sharing knowledge among the participants.

The first presentation was by Jarmo Ruuth on Photogrammetry. Photogrammetry works by combining many (up to several hundreds) photos from different angels and with large overlap. In caves the lightning is a problem; Jarmo has built a set combining a strong light with a GoPro camera. There are several software, including free, eg Meshroom (from AliceVision https://alicevision.org/). StructureFromMotion (point cloud and camera positions calculated by the software); the final 3D model is with “texture”. For longer caves: combine smaller models, but there are problems with that. It is possible to calculate coordinates for points within the cave starting the model outside the cave with a point with known coordinates (eg GPS).

Discussion: Andrea points out that Meshroom is highly customizably (but for Jarmo the default has been working rather fine for the small Finnish caves). Angel recommends VisualSFM (free; http://ccwu.me/vsfm/). Richard has experienced that lightening is limiting; if there are dark sections in the photos they are useless. Also an even lightning is needed, so use external powerful (like 10 000 lumen) lights. It has also been noted that that the individual photos can be really bad / boring / flat … but the “flatter the better” for the end result. Also: Large cave passages with a diameter of more than c 25 m are not really possible for photogrammetry.

Second presentation was by Mats Fröjdenlund on SLAM, LiDAR, Photogrammetry and Drones. He started with “The future speak in our favour!” LiDAR-data can (in Sweden) be obtained from Lantmäteriet (https://www.lantmateriet.se/). Orthomosaic can be obtained using drones. From there build up a 3D-environment. Fix points by direction finding equipment in the cave and by GPS on surface, connecting cave survey with LiDAR-data + orthomosaic from drones => 3D-model. SLAM: Simultaneous Localisation And Mapping. SLAM-software, simultaneously locate itself on the map and survey (create a virtual map of the location). Handheld equipment (geo-SLAM equipment, e.g. Lieca BLK2GO, Semeresent Hovermap).

Drones act as a sensor platform. Output can be Ortho Mosaics, 3D Point Clouds and Meshes, Smart Inspection Photos; 2D: Static tile, Dynamic Map services, etc.

Discussion: Angel has seen some chinese manufactured robots with LiDAR for around 1000 USD! So the price will definitely go down as technology evolves.

Third presentation was by Ola Löfquist on using LiDAR ground elevation models to locate possible cave entrances. Ola described “a low tech approach to something very high tech”. He printed a detailed open LiDAR-ground elevation model over the Swedish karst area Bjurälven, accessed from Fornsök (https://app.raa.se/open/fornsok/). Ola had access to orthophoto + topographic map + LiDAR-data for the same area. Using these data he could locate and, together with six other people, check more than 100 dolines in less than 2 days, covering an area of several kms x 0.3 km. Now remains postprocessing the field notes in a proper GIS software.

Discussion: Richard shared experience from Slovenia, where they recently identified some 5000 dolines! They used a digital copy of the national LiDAR-database. Blausu had to find dolines in Colombia by foot, without access to LiDAR-data … (but using Google Earth topographic overlay and QGIS). Jari tells that similar approach has been used in Finland (but fewer dolines), they also used geological maps to find suitable rocks. João tells about use of stereoscopic aerial photos (old
monochrome from the 50’s) due to lack of LiDAR data; dense forests are then a problem. Robert points out that the availability of LiDAR data varies from country to county. The coverage in Norway is best in populated areas but not so good in other more remote areas. According to João Spain is covered, also Portugal is rather good, France almost? With drones you can cover large areas yourself (but pricey drones, like 50 000 Euro). For surface also photogrammetry and drones can be used as a substitute for LiDAR (light is not the same problem as in caves).

Next presentation was by our host, Jari Arkko, on his experience using iPhone 12 Pro for 3D modelling. Only seven months of experience (and no previous 3D experience at all), and still excited over the possibilities but can also see some limitations. Caves needs to be divided into small segments (c 50 m each). If mistakes are done only that segment needs to be re-captured, but also due to limitations in the software. Jari is using the Polycam app with mixed experience. He is using the iPhone on a selfie-stick (a Ram Mounts X-Grip + Benro MMA28C monopod). With the Polycam app some initial processing can be done in-phone, but is somewhat tricky and buggy (texture data can be lost). Post-processing is necessary! Blender (open software, very powerful but also with big learning curve). Merging is done by binging parts to Blender, align, adjust/remove extra points, correct. Images and movie generation. Case study: Torhola cave (longest karst cave in Finland, c 100 m in length). Case study 2: Lummelunda cave (on the island of Gotland, Sweden): the LiDAR scan shows some details not readily seen in the cave. Case study 3: Kraljicina spilja (Croatia): work in progress; aligning different parts can be problematic if there are no obvious features like cracks that can be used. For sharing the result: model-viewer.dev. Integration with the Finnish on-line cave database luolaseura.fi/luolakanta/kartta.html?lang=en and planetcaver.net/modellist.html (cave models). Going beyond 3D: 3D-models not always best, sometimes a plan view is easier to understand or use. A software for taking slices or plan views of 3D models is under construction (github.com/jariarkko/cave-outliner).

Discussion: Ola confirms that the plan view derived from the 3D-model of Lummelunda cave is accurate and corresponds very well with the DistoX-survey. Angel knows that Ken Grush of the NSS Cartography section is doing something similar. The software CloudCompare (http://www.cloudcompare.org/) can be of interest.

Fifth and last presentation was by Pórir Már Jónsson on his (and the Icelandic) experience with iPhone 12 Pro LiDAR for 3D-modelling of lava tubes. They have experienced problems using DistoX and similar devices using a compass due to local but strong magnetic anomalies, but LiDAR has been working well. The pros with the iPhone 12 Pro is its small size, reasonably cheap, it is easy to avoid creating blind spots, less post-processing, vary fast scanning time, but drawbacks include lower resolution, the software app is not designed for large projects (multiple crashes and data loss), large caves need stitching of individual scans, maximum scanning distance only 5 meters (a selfie stick helps), post processing still needed. Stitching is done using MeshLab (tried Blender), some surveyors use AutoCad for 2D plans. The overlaps are not perfect (but much better results than DistoX due to the magnetic anomalies); the iPhone 12 Pro still use the magnetic sensor but also accelerometers (so sensitive to bumps that ruins the scan, thus difficult in tight sections). Water and ice return limited signal (can’t be “seen” by the LiDAR). Sharing the surveys have been problematic. Post-processing into 2D-maps is useful (see Jari’s work!).

Discussion: Angel recommends using Unity, simpler than Blender. Caves are (often) complex …

This conference is a good starting point to build an international network!

Concluding discussion
Jari: What’s next?
João: A problem is the lack of speciality tools dedicated for cave surveys. Next step should be to try to involve major stakeholders so that there will be enough market for developing suitable tools? Workflows from scans to models should be made quicker? These are difficult endeavours! A larger diverse community is needed! The tools now (like iPhone) are developed for “small things”. We
need more “serious” development. The mining industry? We (cavers) are developing things in our
spare time … modern speleology developed as an answer to important questions like tracing fresh
water movement for consumption in cities etc so obviously very important for society! So try to
mobilise the software industry to develop tools with cave survey as a use case?
Angel: We need software combined with powerful computers. RealityCapture software might be
free within a year? We have to go first to the miners (but no mines in Puerto Rico though!) and
compare needs. Hardware will go down in price. Build yourself a possibility.
Angel: Integration is a key here! If we choose the approach not to “waste” time developing, cave
surveying will be for a small minority of cavers.
Jari: How do we as community continue? A similar event as today in a year’s time?
João: A forum is needed.
“Blausu”: Very good conference! There are so many softwares, etc, so we can create a group that
can survey the different solutions and then put forward recommendations. TopoDroid is a good tool;
how to join/develop TopoDroid so it can be used with a LiDAR scanner?