Cyclops: a cave photogrammetry tool

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***Abstract*—Cyclops is a tool for use by cavers to map and document the caves they explore. It uses photogrammetry and an inertial measurement unit (IMU) to map the cave without having to use traditional mapping tools**

I. Introduction / Background

The Yorkshire Dales is the largest caving area within the UK, and teams of dedicated cavers are constantly finding new and exploring new caves. Once found these caves need to be mapped and documented. The traditional means of mapping caves involves taking meticulous drawings and using analogue instruments to measure "legs" through the caves, and then combining all this data to produce formal surveys. This information can then be used to see where the new cave may link in to other caves and where new caves can be found. This process is however quite time consuming and can be physically demanding; it has become easier recently with the advent of electronic cave surveying tools, but the fundamental workflow remains the same – record legs and draw the cave. This device will allow a new paradigm – simply walk through the cave with this device attached to ones helmet and it records the shape and layout of the cave as it is explored. The images are then analysed and the shape of the cave is deduced from the parallax effect of the images. The IMU allows one to orient the generated map against magnetic north and vertical.

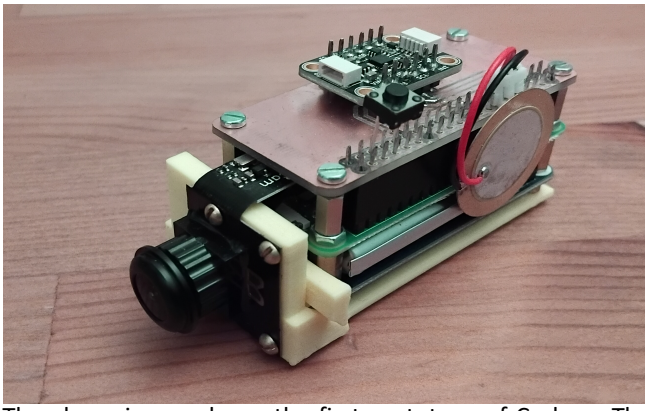
II. Related work

Jordan [1] has extensively explored photogrammetry for cave mapping using a go-pro camera connected with a high powered light – they obtained good results, but found difficulties with flowing water and larger passages. They additionally needed to do a separate survey through the cave to correct for any scaling errors and directional drift. There have also been smaller scale explorations by individual cavers, Alessandri [2] and Ruuth [3].

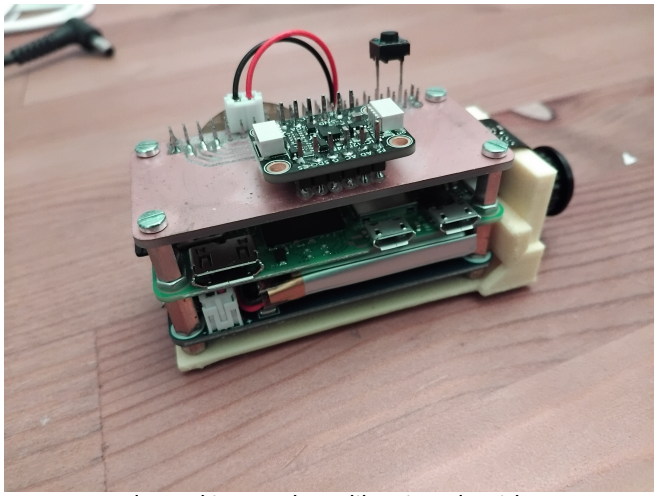
III. Existing prototype sketches/drawings/photos

I have developed a device, using a Raspberry Pi Zero 2, a Raspberry Pi Camera, a WaveShare Uninterruptible power supply Hat, and a self-made PCB which carries an Adafruit TDK Invensense ICM-20948. This is all mounted in a 3d-printed PLA frame, which includes a switch to turn the power supply on and off.

Software wise I have developed a plugin for Gstreamer (a video library/framework) that allows data from the IMU to be recorded as video frames within a Matroska video file – this means that all the IMU data comes with a timestamp which is synchronized with the video feed from the camera.



The above image shows the first prototype of Cyclops. The image also shows a button and buzzer that were later added. The image below shows the Lithium Polymer battery from the UPS more clearly.



I am currently working on the calibration algorithms.

IV. Responsible innovation

In my development process I recycle my prototypes to reduce unecessary electronic waste. Accurate cave mapping can help assess the ground water and hydrology of an area, and can provide information about areas that may be prone to sink-holes which will be useful when developing new housing developments.

V. Author bio

I have been a caver ever since being an undergraduate at King's College London. I have since been on several caving

expeditions to the Totes Gebirge region of Austria with Cambridge University Caving Club. While there I have helped explore many new caves and have been involved in mapping them.

I developed an electronic caving tool, the Shetland Attack Pony[4] which has undergone many changes over the years and is now a successful product, having sold over 100 units. It is fully open source, with all the hardware and software designs available on GitHub[5]. As part of the devlopment work I have developed innovative new calibration algorithms that enable quick and simple calibration in the field.[6][7]

VI. Acknowledgements

I would like to thank the British Cave Research Association (BCRA) who have arranged several meetings where I have been able to meet other cave surveyors and get their feedback and requirements.

VII. References

[1] J. H. Jordan, 'Modeling Ozark Caves with Structure-from-Motion Photogrammetry: An Assessment of Stand-Alone Photogrammetry for 3-Dimensional Cave Survey', [Online]. Available: https://core.ac.uk/download/pdf/127621674.pdf

[2] L. Alessandri, 'Photogrammetric survey with fisheye lens for the characterization of the La Sassa cave', Accessed: May 29, 2024. [Online]. Available: https://core.ac.uk/reader/231746310

[3] 'Photogrammetry for 3D Mapping of Caves'. Accessed: May 29, 2024. [Online]. Available: https://ruuth.xyz/PhotogrammetryfOr3DMappingofCaves.html

[4] 'Shetland Attack Pony'. Accessed: May 29, 2024. [Online]. Available: https://www.shetlandattackpony.co.uk/

[5] P. Underwood, *furbrain/STIC*. 2024. Accessed: May 29, 2024. [Online]. Available: https://github.com/furbrain/STIC

[6] P. Underwood, 'Calibrating the Electronic Compass/Clinometer', *CREGJ*, no. 69, pp. 10–13, Dec. 2007.

[7] P. Underwood, *furbrain/CircuitPython_mag_cal*. 2023. Accessed: May 29, 2024. [Online]. Available: https://github.com/furbrain/CircuitPython_mag_cal