Digital Interval Photography in Caves

Sergey V. Sorokin[1], I.E. Vahhi[2], N.A. Franz[3]

Summary: Digital interval photography can provide unique data for cave research. Short-time recordings can be done with available digital cameras; for example we have successfully used Pentax Optio W10 to record ice stalagmite growth. The number of frames which can be done in this mode is limited by camera battery.

For medium time range external power is required. With external battery to power our W10 camera, we got 1000 frames stretched over period of about 2 month – maximal settings which Pentax software allows to set in interval mode. This setup is problematic if sealing against submersion is required.

For long duration one can use Canon cameras with CHDK software and external microcontroller-based timer. CHDK is third-party software available for many Canon cameras, enabling control over most camera functions. An external microcontroller is required to work as a timer to save power between shots, and to control external light.

To get more control over imaging process, reduce cost and improve reliability we are currently trying to construct self-made interval camera using USB-enabled microcontroller and Web-camera.

The main problem for image quality is condensate on outside surfaces of camera box. We have tried several anti-fog coated glasses and sprays, but none of them helps. We are currently experimenting with glass heating to get rid of condensate.

To increase the amount of information gathered with interval photography we set up various pointers, from which levels and flow direction of water can be measured. To improve visibility even in case of strong fog we use reflective tape to mark our pointers and scales.

Special software was developed to combine camera frames with graphs of measured data for creation of time-lapse films.

Using digital interval photography we were able to monitor caves during flood period, when they are inaccessible for people. The most important result was the cave flood hydrograph.

Introduction

Kulogorskaya Cave system is situated at Pinega district of Archangelsk region at Russian north. Cave system is studied by speleologists from Archangelsk, St. Petersburg, Moscow, Tver and other cities under the guidance of Archangelsk Speleological Association “Labirinth”.

The Kulogorskaya cave system is developed in gypsum rock which forms a plateau. South edge of plateau is washed by the Pinega river, the west edge is formed by the ancient river valley, occupied by Pinega-Kuloy channel. All natural cave entrances are located at the bottom of the west plateau ledge. There are small springs at the foot of south ledge, which drains cave water to the Pinega river during low water level periods. Caves of the area are horizontal and main passages are located near to the water level. Periods of spring and autumn flood are important for cave development, but high water level makes caves inaccessible for people during those periods, so observations can only be performed using automatic equipment.

In recent years in addition to different logging equipment we started to use digital interval photography for our observations.

Some of the modern cameras support interval photography mode by built-in software. For cave photography, among the most suitable cameras are those from Pentax Optio W line of waterproof compact cameras. We started our experiments with interval photography in caves in 2008 with Pentax Optio W10 camera, which was successfully used to record ice stalagmite growth during the period of two days.

Pentax software sets some limits to interval photography settings, namely the number of frames is limited at 1000 and the maximal interframe interval is 99 minutes, but the most limiting feature is a battery power, which limits number of frames which can be done autonomously at about 100. So the maximal time span of interval recording is about 99 minutes x 100 frames = 7 days. This limits possible use of a camera alone for a short-time recording of dynamic processes during expeditions.

[1] *Archangelsk Speleological Association “Labyrinth”, Tver State University. sergey@tversu.ru*

[2] *Archangelsk Speleological Association “Labyrinth”, Institute of Environmental Geoscience RAS*

[3] *Archangelsk Speleological Association “Labyrinth”*

External power setup

As the power was a most limiting factor it was natural to extend available power first. For this we have used 4V 7Ah Sealed Lead-Acid Battery. Output voltage of this battery is close to 3.7 V voltage of original Li-Ion battery, so it can be used without power converters. Unfortunately, the connection with an external battery breaks camera sealing, so we used an external sealed box to protect the camera setup from moisture and possible flooding (fig. 1). Power from this battery was enough to achieve the software limit of 1000 frames. Thus, the session duration was increased to about 3 month.

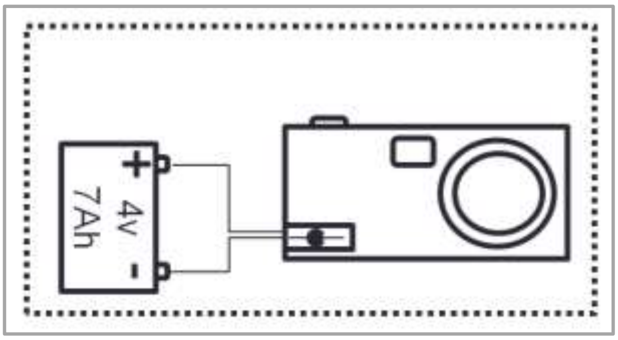

Fig. 1: Structural scheme of first-generation setup. Dotted line shows sealed box.

We have used this setup during summer flood of 2008 and it allowed us get first flood hydrograph of K-4 cave (fig. 2).

Before we have got this hydrograph, it was believed that during spring flood caves of the Kulogorskaya Cave system are directly filled with water from nearby Pinega River, and maximal water level inside caves is equal to maximal water level in Pinega River. It turns out that in fact water level in caves is considerably higher due to melt water from snow cover above caves. This result is especially interesting because it is known that inside caves flood water flows from known entrances (near the Pinega River and Pinega-Kuloy channel) deep into the system.

The achieved result, however, was not ideal. First of all, image quality turns out to be extremely poor. This was due to combination of 3 factors:

- heavy condensate on box surface;
- strong flash reflection from nearby white-colored wall;
- flash reflection from box surface and condensate.

While it is possible in most cases to position the camera so to exclude large areas of nearby white walls, reflection from the box surface is not easy to eliminate in this setup. At least we were unable to significantly reduce it using different sorts of light barriers inside a box. The best solution for this problem is to use external light source which can be separated from camera lens, but this is not possible with this class of cameras.

The second problem was that 3 month of operation time was still not enough to cover all period of high water level in caves.

We still continue to use this setup in settings, where complete camera sealing is not required, so we can use it without external box.

Canon camera with external timer

The main problems of the previous setup were software limit of the number of frames and the requirements of external light. This was impossible to solve using the Pentax camera. Therefore a camera with better control over the settings was required.

The best possible control over camera can be achieved using Canon compact cameras and CHDK software. CHDK is third-party software, available for many compact Canon cameras, which can be installed on a camera flash card (no camera reprogramming is required) and extends built-in software [2]. We have used Canon A460 and later A495 in this setup, as they were the cheapest cameras supported by CHDK at the moments the camera boxes were made.

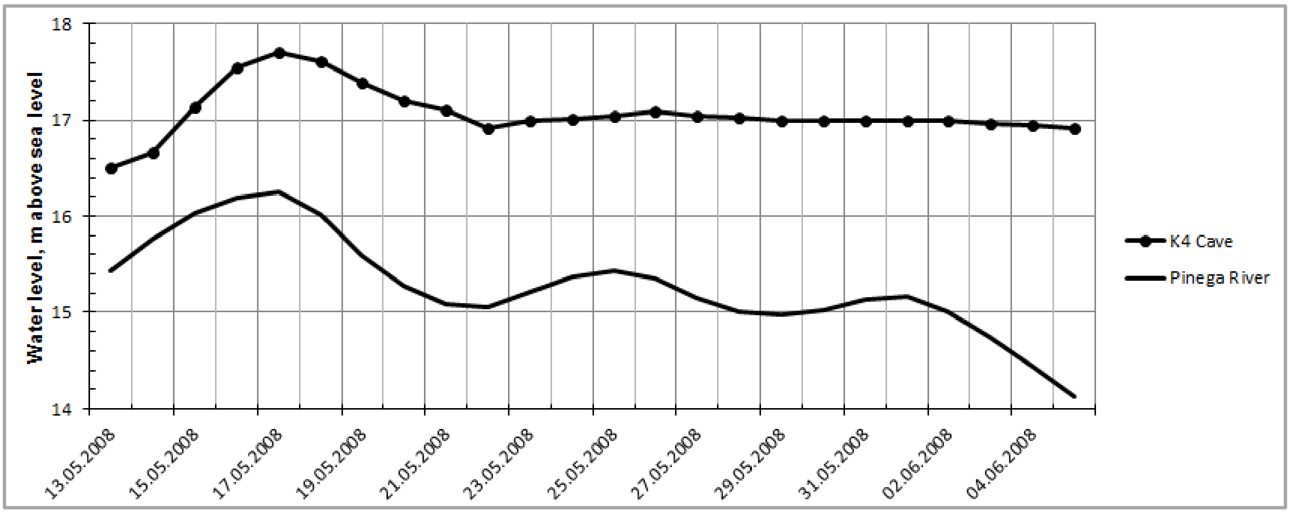

Fig. 2: Hydrographs of Pinega River and K-4 cave in May 2008.

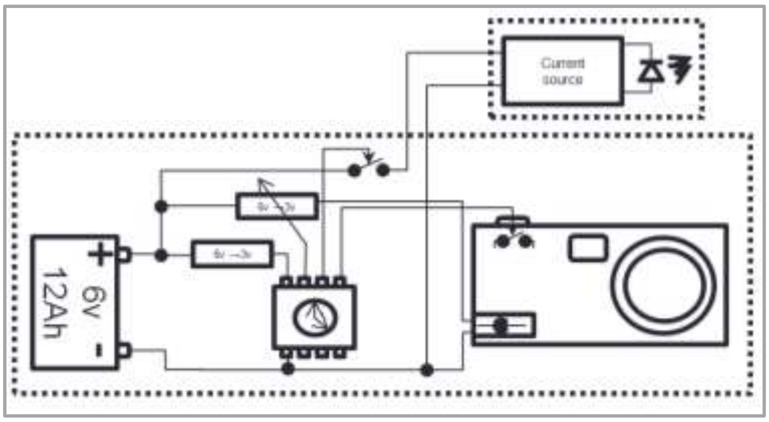

Fig. 3: Structural scheme of second-generation setup.

CHDK allows user-developed scripts to be executed inside the camera, and naturally many interval-photography scripts are available. However, they turned out to be not suitable for long time operation, because it is not possible to turn the camera power off between shoots, and so power consumption is not suitable for battery-power operation.

To solve the problem an external timer was required, which turns camera power on and off at required interval. This timer was implemented using Texas Instruments MSP430F2001 microcontroller [3]. It also controls an external 3W LED light. The complete setup also includes 6V 12Ah SLA battery and power converters for camera and microcontroller (fig. 3). Unfortunately, to control the camera power, one should solder wires to camera power button.

The system operation is as follows:

1. At a preset interval of 3 hours the microcontroller turns on the camera power converter, and the external light. After a short delay it also pulses the camera power button.
2. The camera powers on and executes CHDK start-up script.
3. The script sets the camera settings: turns off the internal flash, sets manual focus distance (to avoid unreliable auto-focus in low light) and makes a short.
4. After several seconds the microcontroller pulses the camera power to turn it off, and switch off the light.
5. After a short while the microcontroller turns off the camera power.

In spring 2009 the first version of this setup successfully recorded first complete flood hydrograph in K-4 cave (fig. 4). As external light was used, image quality was considerably improved. However it was still poor due to condensate.

Later we have tried different sorts of "anti-fog" glasses and sprays, but without any positive effect. The only possible way to remove condensate seems to be heating of the glass in front of the camera. Our first experiment (winter 2011-2012) with a heater showed that the energy available from more or less compact batteries is not enough for the required time span. So we are now testing a camera box with a heater, powered from car starter battery.

Infrastructure

To get numerical data of water level from images, we set up rulers in the camera view. The ruler zero height is then measured relative to height marks network in the cave, which have known altitude above mean sea level. To see water direction we installed additional floats.

As the first experiment has shown that image quality can be very low, we started to put marks of reflective tape at regular intervals on ruler and floats. This ensures that the ruler can be read even in heavy fog or from long distance from camera.

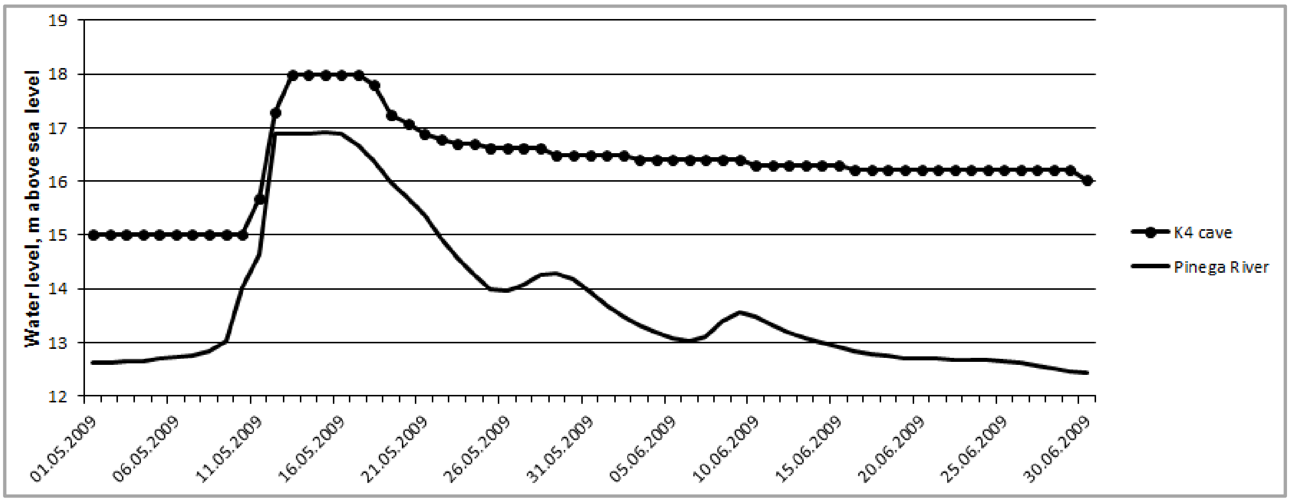

Fig. 4: Hydrographs of Pinega river and K-4 cave in May-June 2009.

Frames from interval camera represent a natural base for time lapse video. We have developed special software, which combines camera images, date and time information and graphs of various parameters (measured water level, external meteorological elements, etc.). The resulting images can be combined to a video sequence by existing software, for example VirtualDub [4].

Conclusions

Digital interval photography allows organizing of a periodical visual observation of hydrological and other processes in cases when the caves are inaccessible for humans or no permanent staff is available.

For more informative photography it is appropriate to place various indicators in the frame. For example, such indicators can be used to measure the water level and flow direction. To improve indicator visibility one can use reflective markers. Additional data can be obtaining by placing temperature or other loggers close to the camera.

Pros and cons of different interval camera setups are shown in the table below.

Currently we are experimenting with building new interval photography system using ARM microcontrollers and various image sensors, so that we will be able to further improve control over imaging system and add other sensors and functions.

		Camera with interval photography mode	Camera with external power	External MCU timer + Canon camera with CHDK
Limitations	Number of frames	Camera battery 100…200	Camera software 1000	Flash card / external battery
	Duration	1-2 weeks	3 month	> 6 month
Image quality problems	Condensate	±	+	+
	Flash reflection	-	+	-
Recommended for		Short duration	Medium duration in dry conditions	Long duration

References

[1] Federal State Unitary Enterprise "Centre of Russian water works inventory and state water cadaster". http://www.waterinfo.ru/ (in Russian only)

[2] CHDK: Canon Hack Development Kit. http://chdk.wikia.com/

[3] MSP430F20x1, MSP430F20x2, MSP430F20x3 Mixed Signal Microcontroller (Rev. F). http://www.ti.com/lit/gpn/msp430f2001

[4] http://virtualdub.org