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English abstract: In this paper, I discuss digital slow motion videography as a method of recording rapidly occurring phenomena that are similar to past dynamic processes. Slow motion videography has already seen use in documenting archaeological experiments. In the past, this required expensive equipment and film. Only very recently has this type of imaging become possible with consumer grade digital cameras therefore allowing it to be utilized by archaeologists much more often, for example to improve our understanding of stone tool making gestures. Until recently, slow motion recordings were primarily used to demonstrate or facilitate an adequate, reflective perception of experiment. However, today, digital media enables more varied footage-based research through multiple recordings, video enhancement and integration of data into computer databases and sharing and learning networks.

Keywords: Slow motion video, Archaeology, Archaeological research video, Experimental Archaeology Data Recording.

Note: please see original link, for embedded videos: http://biografia.archeo.edu.pl/wp/2017/02/16/slow-motion-videography-and-recording-experimental-archaeology-part-i/

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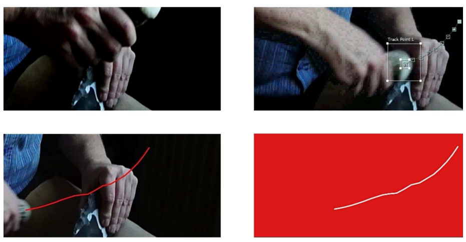
Slow-motion videography and recording experimental archaeology



Michał Gilewski

Abstrakt (abstract in Polish)

Niniejszy artykuł omawia techniki filmowania „slow motion". Techniki te są przydatne w rejestracji szybko wydarzających się zjawisk, z których mamy niejednokrotnie do czynienia w trakcie eksperymentów archeologicznych. Właśnie w ich trakcie odtwarzane są dynamiczne procesy z przeszłości. Istotą proponowanej techniki jest zwiększenie częstotliwości rejestracji obrazu podczas filmowania. Pozwala ona na uchwycenie większej ilości szczegółów, dzięki czemu można systematycznie i szczegółowo odtwarzać zarejestrowane procesy. W ten sposób nawet najszybsze procesy np. ruchy uderzeń przy wykonywaniu narzędzi kamiennych, zwykle niewidoczne dla obserwatorów i trudne do uchwycenia przy zastosowaniu tradycyjnych technik filmowych, mogą zostać zarejestrowane.

Introduction

Digital imaging techniques have long been of great importance for archaeology. The material remains of the past found during the process of excavation are static, and that is why the use of photographic still dominates archaeological imaging. Modern archaeology deals not only with creating frozen images of the past, but also with understanding the variety of dynamic processes that happened [1]. While some processes in past societies occurred over generations, others happened within the blink of an eye. Many examples of the latter are related to studies of how material culture was created, and are often recreated through experiments (Beale, Healy 1975, p. 892; Whittaker 1995, p. 149).

All such cases demand very scrupulous documentation, especially if some of the reenacted phenomena happened rapidly. Even less dynamic events may not necessarily be well understood when observed in real time. Such problems can be dealt with by introducing methods that have already been in frequent use in industrial experiments or sports coaching – slow-motion videography (Verrall et al., 2005). These approaches once required expensive equipment, but now such imaging is possible with some consumer-grade digital cameras or smartphones, placing them within reach of most archaeological investigators (Vollmer, Möllmann, 2011). Such video recordings provide certain characteristics that facilitate not only an adequate and reflective perception of the experiment, but also produce videos with considerable aesthetic qualities as a 'by-product' which are suitable for dissemination among non-academic audiences. In this paper, I argue that the digital format brings certain qualities that allow further analysis based on computer applications.

First, I will discuss the very brief history of using videography (especially slow motion videography) in anthropology and archaeology. I will then present the method in more detail and explain how the new technological means allow for its wider use and new applications. This will be followed by a case study: a test recording of a flint-knapping experiment prepared specially for this paper. I will also include a brief discussion of how video can be analysed using computer technology.

A history of slow-motion videography

In slow motion videography, a series of photographs is captured to record a motion picture. The images are captured at a higher frequency than in regular videography, which usually utilizes a frequency of around 25-30 images per second. In slow motion, this frequency may be many times larger, getting as high as thousands or millions of images (frames) captured every second (Barbash, Taylor, 1997, p. 255).

Slow motion videography has a long history of use in cinematography. The predecessor of this technique was developed in the 19th century through the projects of Eadward Muybridge, which studied motion of humans and animals through so-called stop-motion photographs. They were series of high-speed pictures taken by automated cameras that captured both rapid phenomena that cannot be seen and to "fragment" the time and motion (Wickstead, Barber, 2012; Weinburger, 1992, p. 49). The most famous set documented the motion of galloping horse in twelve photographs and through this process Muybridge was able to prove that in one time the horse can take all its four hooves off ground (Wickstead, Barber, 2012, p.80). This lead to the development ofanalogue, intermittent movie cameras, which could have easily been set to film in slow motion (up to 600 frames per second; see Malkiewicz, Mullen, 2009, p. 39).The first important film utilizing this technique was probably Man with the Movie Camera (1929) by Dziga Vertov (Barbash, Taylor, 1997, pp. 120-121). This famous film was a documentary (in the so-called cinema verite genre) about daily life, and its slow motion cinematography portrays sportsmen practicing a variety of sports like football, hammer throwing and hurdling.

The usefulness of slow motion to document fast or rapid social phenomena led to a quick adaptation of this technique for ethnographic films and research footage (Heider, 2006). Famous ethnographic films include those made in 1947-1951by Maya Deren, which feature slow-motion recordings of extremely frenetic voodoo performances (Weinburger 1992, p. 49), and Timothy Asch's Ax fight (1975), which utilized numerous replays and still frames to slow down and discuss the recording of a fight that broke out among the Yanomamo (Barbash, Taylor, 1997, pp. 31-32). Modern anthropology (along with other social sciences) has further developed the concept of videography as a research tool (see Heider, 2006, p. x-xi; Knoblauch, Tuma, 2011). Recently, video recorded micro-social interactions have been researched using an interpretive approach (Knoblauch, Tuma, 2011).

Archaeology has also taken advantage of filmmaking technologies (see Beale, Healy, 1975; Van Dyke, 2006; Morgan, 2014). The first archaeological films were made in the 1920's and the 1930's (Beale, Healy, 1975, p. 889). As Beale and Healy claimed in 1975, many different genres of archaeological films can be defined ranging from excavation training videos made for professional use to popular science films about sites and whole past cultures [2]. One of the genres distinguished by Beale and Healy are "films of experimental or ethnographic studies which demonstrate or help reconstruct ancient crafts and technologies" (Beale, Healy, p. 891). As they note, such films can be used for study and research, since through film, one can observe phenomena that are difficult to register using still photography. Additionally, film can slow down rapid phenomena that the naked eye is unable to register, such as the example of "the slow motion shots of Donald Crabtree flint knapping in the lithic technology films one can actually see how the blade or flake is formed as a blow or pressure is applied to the blank" (Beale, Healy, 1975, p. 892).

Since flint knapping depends on making a series of very rapid movements, slow motion recording has frequently been used to record this phenomenon for popular science, training films and arthouse cinema (Whittaker, 1995, p. 149, Witold Migal, personal communication). This is, however, not without its limitations, as the archaeologist and flint-knapper Witold Migal recalls. Migal showed me a flint-knapping performance during the shooting of an artistic short film Litofon (1995), where he performed flint-knapping to process stones required for the replication of a musical instrument based on such stones. Slow motion filming utilizes large amounts of analogue film, thus greatly increasing material costs. The authors of the film limited the slow-motion recording to only a single take because analogue film was used, and almost all film tape in the camera's film magazine was consumed in a few seconds of recording (Witold Migal, personal communication).

The slow motion technique has been used mainly for demonstration purposes, while recording research footage was apparently much less frequent. Some techniques were used for understanding very specific problems related to the use of atlatl spearthrowing devices (after Whittaker, 2010, Whittaker, 2012). In my literature survey, I was unable to find more research footage or any detailed description that has been clearly identified as recording with slow motion.

Instead of using expensive film, digital imaging techniques use electronic sensors, with the resulting implication that digital video production does not involve the same high material and processing costs. Because of this, archaeologists and archaeological experimenters have been using this technology since the 1980s (Van Dyke, 2006; Whittaker, 2004). For most of this time period, however, a slow motion videography mode was not featured on the recording devices intended for mass-market customers. Instead, it was only featured on specialized, high-cost camera models and thus not feasible for low-costs projects.

Meanwhile, regular video recordings have become an important part of the flint knapping process. John Whittaker (1995, p. 149) explains: "[t]he physical actions of flintknapping are difficult to explain in words [...] illustrations are inaccurate, and [...] inadequate to convey complex three dimensional motions [...]". John Whittaker in American Flintknapping notes the important role of videos in teaching and documenting knapping experiments. Such videos were even shared using videocassettes (Whittaker, 2012). The Internet has made video sharing significantly easier with thousands of flint knapping videos existing on the popular video sharing service Youtube. However, when this article was prepared, only one digital slow motion video of flint knapping experimentation had been posted on Youtube, illustrating that slow-motion videoformat has yet to become a widely-accepted trend.

The first consumer camera able to shoot in slow-motion mode was introduced in 2008 and allowed the slow-motion technique to be applied much more often (Vollmer, Möllmann, 2011). Such videography modes are now available in an increasing number of cameras and digital video recorders (especially so-called sports cameras) and are even featured in the leading smartphone devices (such as the Samsung Galaxy and iPhone series). It should be noted that modern smartphones can run special "couch" applications that allow for the recording of sport videos that can be annotated with drawings and voice recordings for the purpose of performance self-analysis. Beyond these initial stages, further advances in affordable slow-motion capture are promised by the recent announcement of, crowd-funding projects aimed at designing low-cost specialized equipment on the internet (Blain, 2014).

My experience in working with slow-motion began with shooting research footage of the archaeological experiment that I observed during a practicum in the National Archaeological Park Tak'alik Ab'aj in Guatemala (see Gilewski, 2015). This application of digital slow motion videography convinced me that this technique is a very useful tool for archaeological scientific research. Because of this, I decided to prepare a test recording of flint knapping, which, in my opinion, is the most obvious application of this technique, to determine how this kind of research footage can be used for analysis.

Experiment, documentation and processing
Witold Migal, an experienced flint knapper and archaeologist from the State Archaeological Museum in Warsaw, agreed to perform flint knapping experimentation that would be recorded. He also advised the author on issues of flint knapping.

I filmed the knapping of a biface, using a flint stone core, a smaller stone for preparatory grinding and soft antler hammers for percussion. Unfortunately, lighting was limited to natural sources. During the experiment, various steps of the knapping process were shot at differing magnification levels. The process of filming took two hours during which 83 slow motion videos were produced. The slow motion shots were shot at two speeds: 400 frames and 1200 frames per second. The camera saves them as .mov files encoded using the popular MPEG-4 AVC codec set to replay at the speed of 30 frames per second. This results in the time being perceived as 13.33 and 40 times slower, respectively. Due to technical limitations, the camera could produce only five seconds of slow motion video at a time, so we were unable to produce a continuous video documentation of the process. The 83 slow motion videos of both types already have a total slowed down playback time of more than 92 minutes. Four videos were shot at regular speed, including a "faster standard" of 60 frames per second. After the whole process, a short direct testimony recording of Witold Migal describing the process was produced. An additional objective was to determine how usable the regular speed videos are in comparison to the slow motion videos, and if the software-generated slow motion-like effect (Twixtor plug-in) is of any use in such an application (see details below). If so, the vast amount of archival video footage could be slowed down and provide a new quality for adequate analysis. All imagery produced for this paper was created using a the Nikon 1 V1 camera with a standard 10-30 mm 3.5-5.6 lens, which can be bought for around 250 Euros. All videos were produced in progressive mode, meaning each frame was shot in full resolution, and no videos were made using interlacing. The regular speed videos were shot at 1280×720 resolution, while the slow motion videos were shoot at 640×240 (400 fps) and 320×120 (1200 fps).

Some popular software was used to process the video. For the regular-speed digital video, a visual effect that uses existing frames to interpolate "intermediate" frames was used by taking advantage of "plugins" and software editing programs. Here, a trial version of a plugin called Twixtor [3] and the Adobe After Effects software (a part of the popular Creative Cloud software suite) were used to process the video. I selected one video that featured a rapid blow to the core. The video was intentionally shot at a regular but more frequent rate of 60 fps in the progressive mode. Adobe After Effects was also used to produce a "match moving"-based visualization.

The results: regular video processing, motion recording and visualization
After processing, a regular speed video converted to slow motion video was analysed. While some slower motions (preparatory grinding for the strike) are presented adequately in the playback and can be efficiently followed by the human eye, the same cannot be said about the main strike. The preparatory motions were slow enough to not have significant changes occur between the registered frames, allowing the software to produce adequate artificial frames. These can be observed during slower speed playback. However, the main percussion motion itself is too quick to produce such imagery which would provide the software a basis to calculate non-existing frames that would properly display the motion. Instead, what results is the same blurred image being displayed for a much longer period [4].

Such movements can be efficiently portrayed only in proper slow motion recording. In the 400 fps video, it can be observed that some percussion movements last approximately 30 frames or one second. At the regular video speed, image sampling is too slow to capture more than 2-4 frames in the movement.

Because the slow motion video records around 30 frames during the motion of a single strike [5], more aspects become clear. This also allows for comparisons between strikes, for example between good strikes and those that were poorly executed. Selected key frames can also be used to represent the motion (see Figure 1).

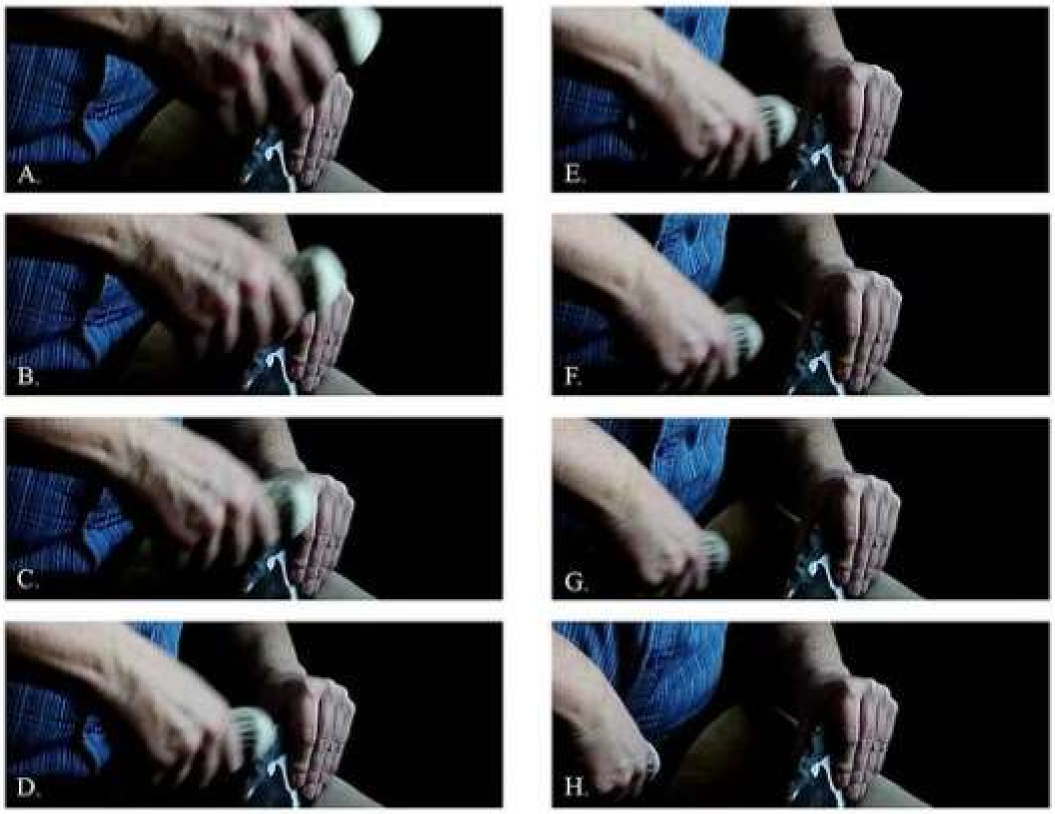


Figure 1. A percussion movement presented on selected key-frames.

Also, a simple illustration and interpretation of the movement can be executed using a simple match moving feature (“motion track effect”) in Adobe After Effects. In the selected video, this was used to track the bone tool used to strike the biface. The program produced a path that was converted into a vector drawing (see Figure 2 [6]). Such a path, although it remains a two-dimensional projection, provides a good, approximate overview of the motion and thus enhances our ability to understand it [7]. Such snapshots of different movements can also be used for comparison. This interpretation represents the whole motion so they can be efficiently integrated with movie files in computer databases.

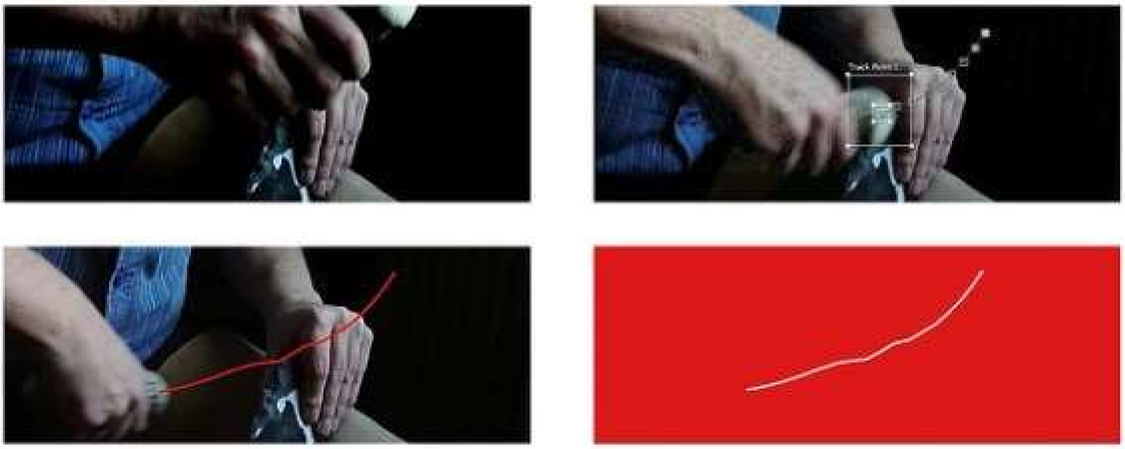


Figure 2. Match-moving-based visualisations of the percussive motion.

It must be noted that the files are very easy to store and share. What is of even greater importance is that the recordings can be integrated into databases, bringing some interesting formalized frameworks for researching ancient craft-production related gestures.

The video materials were reviewed by Witold Migal and myself. Of great importance was Migal's critique of such techniques from experience. An experienced flintknapper, his initial skepticism changed to emphatic approval after seeing multiple videos documenting the difference in and noting how such few videos could scrupulously document details of (i.e. ineffective moves). Of some concern to him was that the static character of flintknapping archaeological material makes advanced interpretations of what techniques and gestures were used limited. However, he also noted that the modern experimental re-creation can be viewed from a different perspective, for example for permitting the recording of a level of detail not visible to the naked eye in the individual variability of practice of modern flintknapping. In this sense, the results can be described as enabling new, more reflective and insightful perception of archaeological experiments and may lead to interesting new developments of the discipline (see Gilewski, 2015, p. 140) [8].

Any discussion of technique would be incomplete without mentioning some technological alternatives to recording data. Motion capture is currently only being utilized for recording human movement and related cultural heritage (see Dunn et al., 2012; Dunn and Woolford, 2012; Stavrakis et al., 2012). The technique is, however, based on specialized equipment – it requires the use of multiple high-speed cameras. Using this technique, much sophisticated three-dimensional information about motion (for example positions of objects per frame) can be recorded. However, the use of motion capture means that significant effort, preparation and budget must be secured to create such documentation. In the case of slow-motion recording, the minimum equipment only includes a camera (and tripod), which making it a cheap and easy alternative to motion capture.

Conclusions

The emergence of consumer digital cameras able to record in slow motion is of great benefit to the field of archaeology. The technique, which has a long history in archaeological film making, now has a much greater breadth for potential implementation. This not only means that archaeological experiments, which are often conducted on a low-cost basis, can also use this kind of documentation, but that a large number of these recordings can be made. This can be crucial for examples such as flint-knapping, where slow motion films were limited to educational and popular science purposes due to costs, while regular videography (that is less applicable in this application) has very frequently been used for analysis, self-evaluation purposes by both scientists and hobbyists. Now, slow motion can be more freely applied to these and other and similar purposes while benefiting from the digital nature of the media. Not only can the videos be easily shared (see Whittaker, 2012), but research footage can be produced much more often, and this greater amount of data can be handled by means of integration into databases for computer based processing and analysis.

Finally, it must be added that such videos facilitate very "reflective" analyses. The ability to self-reflecta virtue of great value to archaeologists. Archaeologists who are trained to imagine a past which cannot be seen are now permitted to observe events that occur in the blink of an eye. This also produces a very aesthetically pleasing by-product that may be used not only in science, but also in art. As I already mentioned, slow-motion flint-knapping was used as a portion of an artistic experimental film. Perhaps, wider possibilities can contribute to other film projects mixing archaeology and art. The application of this technique brings archaeology closer to other disciplines that use videography to observe various phenomena.

Endnotes

[1] This relates to some important theoretical discussions in archaeology (see Johnson, 2010, p. 52).

[2] However, Collen Morgan (2015) suggests the "archaeological film" definition should be applied only to films created by archaeologists.

[3] Because a free trial version was used, the images are marked with thin red lines indicating the full version was not used. For the intended quality test purpose, such diminished aesthetics are of minor concern.

[4] The video can be accessed here: https://youtu.be/WkpdFJgtBcE.

[5] See example: https://youtu.be/bq3_NnyYPfs.

[6] See also video here: https://youtu.be/8E68ZQ08jkI.

[7] As Tim Ingold (2007, p. 72-75) observed such ideas of tracing the line, and fragmenting it to "freeze-frame points" lead to analyses of the gesture and the ability to capture it as tangible "finished object".

[8] See Wickstead and Barber (2012) for example of proposition of how greatly visualizing methods of archaeology and its "notions of vision" were shaped by new technical developments.

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