Filming Avalanches

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1 Key Points

This section contains a few suggestions for filming avalanches so as to maximise the accuracy of subsequent analysis. Later sections give some of the explanations for these choices and other alternatives.

- Use a high quality 3 CCD DV camera.
- Film face on to the slope as high as possible. The camera position should be accurately measured.
- The camera should be set up so that the avalanche moves horizontally across the camera screen.
- The camera should be kept still for the duration of the avalanche and not zoomed or panned.
- All camera settings should be set to manual. If the camera alters the focus, white balance, or exposure during the image sequence the analysis is more complicated.
- Standard principles of photography apply for lighting. When possible shoot with the sun, or light source, behind the camera by choosing the camera location and time of day carefully. Shadows and other effects such as glare, can be dealt with but increase the complexity of algorithms and can reduce accuracy.
- There should be at least a dozen features visible across the field of view that can be accurately identified on a DTM (Digital Terrain Map). These points should be identified at the time of filming and carefully recorded. Still photos should be taken to aid in their identification.
- Synchronisation should be achieved with other video cameras or data recorders by broadcasting an audio signal over a radio which is recorded by the camera.
- The location of the camera should be fixed and carefully measured including height above the ground. a permanent mounting would be desirable.

2 Choice of equipment

Analogue video cameras. No longer popular but legacy cameras may be used. This is the least suitable choice. Consumer grade recording formats are very poor quality. Tapes can degrade and cannot be copied without a reduction in quality. High quality digitisation requires specialised equipment that includes time base correction. Most PC cards significantly degrade the image. The best option is to use a professional company. Failing that the videos can be directly recorded using a digital video system. This introduces some compression noise, but this is probably not significant given the low quality of the source.

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Digital video cameras. Nearly all modern video cameras use DV (Digital Video) format. Other systems (DVCAM, DVCPRO and Digital8) use slightly different tapes and recording speeds, but use the same basic format and data rates and so are identical in quality. Because they are digital the tapes can be copied without loss and easily transferred to computers.

DV is an intraframe block based DCT (Discrete Cosine Transform) lossy compression format. This means that each frame is compressed individually in a similar manner to JPEG. Roughly speaking luminance data is taken from every pixel and chrominance data averaged over four adjacent pixels. The data then undergoes a 5:1 compression resulting in data rates of around 315kB/s. The overall compression is thus 20:1 for the colour information but only 5:1 for the luminance.

The quality of the compressed images can be improved, by ensuring that areas of the screen where the avalanche will not reach have little picture information. In a laboratory setting this is easily achieved by ensuring that as much as possible everything is the same colour apart from the flowing material. The reason this improves the quality is that before the quantisation level is set for each group of macroblocks (16x16 pixel blocks for PAL), they are shuffled. So that if some of the macroblocks have little information more bandwidth is available for the other blocks.

The resolution for DV format cameras depends on the video system as follows:

system	frame size	sampling	frame rate	field rate
PAL	720x576	4:2:0	25	50
NTSC	720x480	4:1:1	30	60

Both systems are interlaced, which means that each frame is divided into an odd field, consisting of all the odd numbered lines, and even field consisting of the even numbered lines. Thus for PAL there is an effective vertical resolution of $576/2 = 288$ lines at 50 fields per second. If one wishes to resolve the position and speed of an avalanche downslope, it is therefore more than twice as accurate if the avalanche moves horizontally in the camera screen as the resolution is 720 pixels at 50 fields per second. In this case the lateral spreading of the avalanche will have lower resolution but this is a much slower process so will not be significantly effected.

Cheap video cameras only have one CCD to detect all three colour components. With this system the full resolution of the DV format can not be obtained. Much better results are possible with more expensive 3 CCD cameras. Among 3 CCD cameras the more expensive ones have significantly better optics. Given the difficulties involved in obtained avalanche videos it is worthwhile to use high quality cameras.

Machine vision cameras. These are cameras that connect directly to a computer and the images are usually stored on a hard disk. A great range is available with resolutions up to 4000x4000 and frame rates of thousands of frames per second. These offer the best quality and there are no compression losses. However, the cameras, computers and interfaces are expensive compared to consumer camcorders and harder to operate. They are very suited to laboratory experiments, but would require considerable effort to use in the mountains. Nevertheless, the increased resolution would enable much more accurate measurements.

3 Camera Calibration

Camera calibration is the process of determining the internal camera geometric and optical characteristics (intrinsic parameters) and/or the 3D position and orientation of the camera frame relative to a certain world coordinate system (extrinsic parameters) (Tsai, 1986; Tsai, 1987). For the Tsai camera model there are 5 intrinsic parameters (focal length, aspect ratio, nonlinear distortion and optical centre pixel coordinates) and 6 external parameters (3D world coordinates and orientation). In theory the camera intrinsic parameters can be measured for each aperture, focus distance and focal length. These are fixed for each camera. In practise this information is not generally available for avalanche films and their intrinsic parameters must be inferred. Again in theory the extrinsic parameters could be directly measured. Camera position can easily be measured extremely accurately using differential GPS. Camera orientation is more difficult and it will usually be better to infer this from the pictures.

When some of the camera parameters need to be inferred from the pictures this can be done by identifying *control points* in 2D pixel coordinates and 3D world coordinates. The camera model give a mapping between the two coordinate systems that depends on the parameters. Thus the parameters can be found by minimising the difference between the 3D coordinates projected onto 2D pixel coordinates. For this optimisation procedure to be accurate, control points over a volume including the experiment and the size of the screen must be accurately identified. This is frequently the hardest stage in analysing an avalanche video, and in some cases is impossible. Without an accurate determination of the camera parameters it is impossible to extract quantatitive information from a film so careful consideration should be given to this problem at any sites where avalanches are to be filmed. If all the camera parameters are to be determined at least 6 control points are necessary. However, for such a small number of points the optimisation is usually unstable and thus inaccurate. Ideally there should be 20 points or more.

The above discussion is framed for fixed cameras, where the camera parameters do not change during the film. That is, the camera is not moved or zoomed. If the camera moves with the avalanche then there must be sufficient control points visible in each frame to calculate the parameters. For this reason it is strongly suggested that cameras are not moved while filming avalanches and that the focus, aperture and zoom are locked.

Fixed locations should be used for filming avalanches and their positions accurately measured using differential GPS or photogrammetry. The height of the camera tripod should be measured when the film is taken. Inaccuracies in determining the exact optical centre of the camera will not be significant for snow avalanches, but will be important for laboratory experiments. In this case the optical centre the camera can be inferred from control points. High resolution photos should be taken using still cameras as this may help to resolve ambiguity in locating the control points.

Control points should be identified on the terrain so that ten to twenty will span the field of view of each camera from its fixed location. These points must be clearly visible under the winter snow-cover and there positions should be accurately referenced to a DTM using differential GPS or photogrammetry. These points could be natural rock formations or artificial objects such as ski lifts. Alternatively purpose built, high visibility structures could be installed.

For laboratory experiments control points can easily be fixed to the experimental structure and carefully measured.

3.1 Ryggfonn

Figure 1 shows possible control points from the Ryggfonn test site. It should be possible to identify all the points marked 'X' on a digital terrain map. The points marked 'O' can only be identified as lying somewhere on the ridge line in the foreground, but they can still be used as a single constraint. By choosing many points it should be clear if any points are misidentified so that errors can be corrected.

4 Synchronisation

If two or more cameras are to be used or other data recorded the different systems should be synchronised in time. It may be possible to synchronise cameras by changes in the images, such as the explosion that triggers an avalanche, but this is inaccurate. A better, but still very simple method, is to broadcast an audio signal by radio. This can be recorded by the video cameras as well as data recording systems.

For natural snow avalanches that last many seconds this is probably accurate enough and enables synchronisation to within a field or so (1/50 s). For laboratory experiments that may only last a few tens of frames more accurate synchronisation is desirable. This can be achieved by using a series of LEDS that are rapidly switched on an off by the data acquisition system. For example if the shutter speed is 1/250 s then 5 LEDS that each light up for 1/250 s in turn should be chosen. There will be one field where two LEDS are partly lit and this then fixes the time of the frame to within 1/250 s.

5 Literature

(Sabot et al., 1998) contains video data from an avalanche Raspe Roies, from the Boí Taüll ski resort in the Pyrenees, northeast Spain. They used an active contour tracking algorithm described

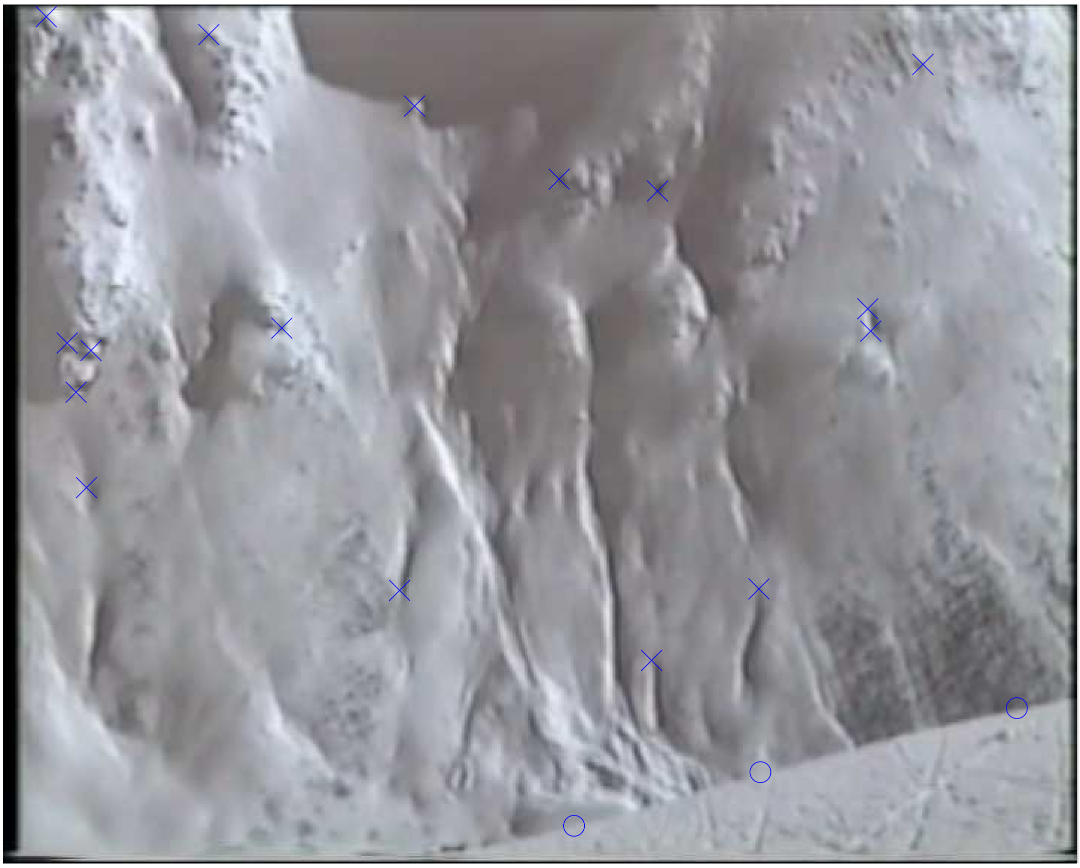

Figure 1: Picture from Ryggfonn with possible control points

in (Marco, 1995) and (Latombe et al., 1997). They were only able to extract the edge of the avalanche over a small part of the track. This method was also applied to an avalanche from Vallèe de la Sionne.

(Nishimura et al., 1995) describes contour extraction from a video of an avalanche in 1993 in Ryggfonn, though the method used was not described. The front velocity was calculated and the avalanche width. Notably the avalanche height profile was calculated by measuring the edge of the shadow cast by the avalanche.

(Briukhanov et al., 1967) developed stereophotography to measure the evolution of the volume and velocity of avalanches. This is a very powerful technique, but requires high quality pictures from at least two cameras. Photogrammetry using single pictures to measure release and deposition volumes has been performed more recently by (Vallet et al., 2001) at Vallèe de la Sionne. (Vallet et al., 2004) use three video cameras at Vallèe de la Sionne to track features on the surface of the avalanche from which they deduce the variations in avalanche height, volume and velocity.

(Kawada et al., 1989) describes manual front tracking of a small artificial avalanche released in Kurobe canyon on 1 February 1988.

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