Choosing a video codec for the remote operation of a drill machine

Remote operation of machines is becoming more and more common, especially in hazardous places like mines. Atostek has designed and implemented a video monitoring system for the remotely operable drills of Sandvik Mining and Construction. During this project the lights, cameras, video encoders, and several other parts of the system were reviewed and chosen. This article discusses the specific question of how to choose a video codec for a remote monitoring system of a heavy duty machine.

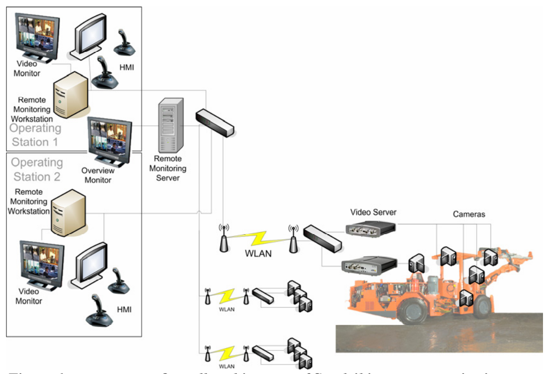

Figure 1. ***Overall architecture of Sandvik's remote monitoring system of a drill machine.***

Remote operation of machines, especially the ones used in hazardous or unpleasant conditions, such as in mines, is becoming more and more common. IP network reaches the machines, and this makes it possible to move control, video, and other data to and from the machine in a standard media. Hence, wide range of commercial devices and applications can be used. Atostek's expertise on video encoding and machine vision gave us an opportunity to participate in a remote operation development project for Sandvik Mining and Construction.

In this article we will discuss the video encoding technology and explain some of the challenges that need to be taken into account in a project like this. We will also tell you about the case Sandvik Mining and Construction; Remote Operation.

Video codecs

Video encoding is a process where a stream of digital video images is compressed with a video codec. There are several popular video codecs on the market, of which MPEG2 is the most well known since it is used on DVDs and digital video broadcasts. Other codecs are MPEG4, DivX, XviD, WMV, H.261, H.263, MJPEG, and so on. For list of codecs see [1].

The codecs have been implemented for different kinds of applications. H.261 was standardized on year 1990. It was designed for video conferencing via an ISDN line. MPEG-2 on the other hand was designed for high bandwidth video transfer; hence, it is used in digital video broadcasts (of standard and HDTV quality). MPEG-2 was standardized in the year 1994. MPEG-4 is a descendant of MPEG-2. It was standardized in the year 1998 and it adds some multimedia features to MPEG-2 and it is designed for a wide range of bandwidths. Most of the currently used video codecs are derivatives of MPEG-4. MJPEG is widely used in digital compact cameras for video recording, and in IP cameras for video transfer to the web browser. MJPEG is not standardized.

Compression methods

A motion picture is a series of still images, which are presented to the viewer in a sequential manner. There are several ways for the video codec to compress data like this. Images can be compressed separately, or the correlation between the images can be utilized. Knowledge of the image content can also be used to achieve a better compression ratio.

The simplest method is to compress each individual image separately. This method yields a low compression ratio and a short latency. Latency here means the time from image acquisition to image transport. When compressing an image, the knowledge of its content can be used to get a better compression ratio. This is called spatial redundancy. Furthermore, the knowledge of the human visual system gives us an opportunity to remove from the image some data that humans are not able to see.

If a better compression ratio is required, the correlation between images has to be taken into account. This is called prediction. A prediction algorithm calculates the prediction parameters from consecutive images, reconstructs a prediction image, and then calculates the difference between this and the original image. Only the difference and the prediction parameters are saved. One way of doing the prediction is to predict the motion in the image. This yields good results on objects that move steadily over the image. Movement that is irregular is hard to predict and causes the compression to fail badly.

There are two main methods to do the actual image compression: lossless and lossy. In lossless compression no image data is lost during the operation. The image can be reconstructed fully from the compressed stream. Lossless compression gives approximately compression ratio of 2:1 of the original image. Lossy compression on the other hand removes information from the image that it thinks humans cannot see. The error that it produces to the image becomes more visible when the compression ratio is increased (see Figure 2). But the image size is reduced significantly. Typical compression ratio for lossy compression so that the image still looks like the original is around 10:1. With future algorithms even a better compression ratio can be achieved. Video sequences can be compressed immensely. Their compression ratio is typically around 300:1.

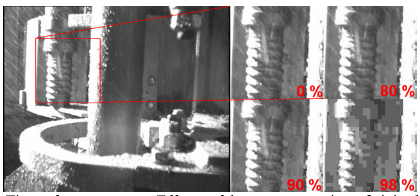

Figure 2. ***Effects of lossy compression. Original image on left and same image with 0%, 80%, 90%, and 98% JPEG compression levels. Resulting image sizes are 30KB, 17KB, 12KB, and 7KB respectively.***

Case Sandvik Mining and Construction; Remote Operation

The goal of this project was to create a video system to be used in remote operation of Sandvik products. The project started with a study, where a video codec, IP video encoder (video server), cameras, and lighting were selected. Atostek proposed the video codec for Sandvik, and did the architectural design of the system. Video server, cameras and lighting were selected in co-operation with OptoFidelity Oy. (See Figure 1.)

There were three major issues that were identified to be crucial in selecting the video codec for the remote operation; bandwidth was highly limited because of the WLAN link to the machine, latency from remote command to a visible change on a screen had to be good enough for remote operation, and image quality was not to be neglected.

In the first phase, Atostek made software that was able to measure the latency from sending a remote command to a visible change on a screen. The video server was also in the loop so it was easy to test how different video codecs and parameters affected the latency. During this phase the stability of the latency was discovered to be highly important.

Especially MPEG-based codecs and MJPEG were studied. These two codecs were supported by the video server. The major difference between these codecs was that MPEG uses motion prediction. This is known to produce higher latency than when motion prediction is not used. Furthermore, latency of MPEG is not as stable as MJPEG because it needs more processing power and the sending order of the frames is nonlinear.

MJPEG gave the shortest and most consistent latency. This was due the fact that it doesn't use motion prediction. A downside was that MJPEG uses more bandwidth than MPEG. When the drill machine is operational it shakes a lot and codecs that use motion prediction do not perform well for shaking video sequences.

The latency measurements, lighting, and camera tests were executed in an authentic environment. The results were collected into a report, on which Sandvik based their decision on the technology used in the system.

After the first phase, Atostek started the system implementation. In this phase the narrow bandwidth was taken into consideration. There were up to four video streams that had to be transferred. All of the streams could not be transferred with the best possible quality. However, the operator of the machine did not have a need to see all the video streams with the best quality so this made it possible to create a bandwidth management feature to the system. This feature dynamically changed the parameters of the video streams to match operator's viewing scenario, and it kept the bandwidth consumption under the required limit. Bandwidth management made it possible to use a better quality video on the streams that were most important for the operator at a certain point in time.

Finally

The video codecs have been designed for different purposes. One codec does not work in all of the applications. Knowledge of the internal operation of the codecs and testing of the codecs is needed when choosing a video codec for a certain application.

Sandvik's remote operation system was finished on schedule, and it is now installed and operational in the mine of the end customer.

Knowledge of video codecs and the architectural design of systems are examples of Atostek's expertise. You can go to our website for more information.

References

[1] http://en.wikipedia.org/wiki/List_of_codecs#Video_codecs

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