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## White Paper

# Bringing Pictures Back to Life - How Much Does Your Content Mean to You ?

December 2011

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### Part 1: Film Marks

#### Abstract

In the digital age of moving pictures: of DVD, HDTV and Blu-ray, the creative and historical significance of film preservation and restoration is now matched by a tangible commercial importance.

Little of what is transmitted on a multitude of digital television channels is new content; it frequently consists of repeat broadcasts, archive material and "classics" from an earlier age. To create masters for broadcast, DVD or Blu-ray production, which meet the high quality expectations of consumers equipped with their new large scale High Definition TV's can be a challenging business. Especially as any content that originates from more than about ten years ago, probably needs some form of restoration.

This paper will discuss some of the restoration techniques currently available for the removal of picture artefacts caused by damage to the film or by the accumulation of surface dirt and dust (film marks). It is the first paper in a series that is particularly targeted at assisting content owners in making the right choice when deciding how to make the most of their valuable assets.

#### Introduction

The very first photographic images created by the French inventor Joseph Nicéphore Niépce at the beginning of the 19th century took hours of light exposure to create and would quickly fade away.

Over the entire 200 year history of film from George Eastman's invention of rolled photography film in 1888, Edison's Kinetoscope in 1889 and the first movie show created by the Lumiere brothers in Paris in 1895, to the creation of Hollywood at the beginning of the twentieth century through its golden era between the first and second world wars and the introduction of sound to the movies, there have been real challenges associated with maintenance and preservation of the medium.

Up until the nineteen fifties, Hollywood was still shooting with nitrate film. This is notoriously difficult to preserve and liable to literally return to dust if not stored and maintained correctly with frequent inspection. As it decomposes it shrinks and yellows. To add to the challenge, the material is flammable and explosive and once on fire, extremely difficult to extinguish (alarmingly, the constituent nitrocellulose doesn't require air to stay alight as the chemical reaction is oxygen producing so nitrate film can be fully submerged in water and keep on burning). This undesirable property meant that without real care, there was the danger of losing a whole film

archive to fire as happened at many of the major studio vaults including Universal in 1924, Warner Bros. in 1933 and 20th Century Fox in 1937. There was also a risk to the public as evidenced by the Glen Cinema tragedy of 1929 that cost the lives of 71 children in Scotland.

It has been reported that the return of Steven Spielberg to the original master of Jaws (shot in 1975) to discover it badly decomposed only a few years after production proved to be one of the triggers drawing attention to the need for film preservation in the United States. By then, the nitrate film had been replaced with cellulose acetate-based 'safety' film, which although no more flammable than paper suffers from 'vinegar syndrome' if exposed to heat and humidity causing the film to warp and become un-useably brittle. The name refers to the distinctive smell of the degraded film and the problem is contagious causing devastation to film stocks if it spreads throughout an archive. Before the eighties and nineties brought in a period of greater focus on film preservation, the film studios had made little effort to preserve their back-catalogue. They would often return to the original camera negatives repeatedly for hundreds of prints scratching the emulsion and causing untold wear and damage. As Harrison Ford ad-libs in Spielberg's Raiders of the Lost Ark (1981) "It's not the years, honey. It's the mileage."

The major film restorations of the late twentieth and early twenty-first century are well documented and often much publicized. The big budgets available and the pains-taking work by industry experts to restore films such as Metropolis (1927), The Wizard of Oz (1939), Vertigo (1958) and The Godfather (1972) are fascinating chapters in the history of film post-production. They often involve years of research in film archives around the world to identify alternative release prints or duplication masters where the original camera negatives are unavailable or suffering from decay and decomposition. Once the film is re-assembled the process of color grading and artefact repair can proceed to create a new restored master with strikingly improved look and sound while maintaining the integrity of the original creative process. These big budget restorations are of course the exception rather than the rule and most films aren't fortunate enough to receive this kind of treatment. Of the millions of reels of film archives that exist around the world, much will be in poor condition, and more is being generated all the time. Despite the growing popularity of high resolution digital cameras for moving picture production, the majority of new features are still shot using 35mm film, the de-facto standard introduced by Thomas Edison more than 100 years ago. The good news is that restoration techniques are improving all the time and digital image processing means that restoration is available for almost all content, without a six figure budget!

## The Problem of Film Marks

One of the many possible artefacts that can be found on film originated material is the obscuration of picture detail by dirt on the film, alien bodies such as dust, hair or film fragments, or damage to the emulsion surface. It is clear that only a very small obstruction within a 35mm film frame will translate to a significant artefact when displayed with a cinema projector or on a large-scale high definition television screen. Consumer television screen sizes have grown significantly in the last ten years without a corresponding increase in the sizes of the houses they inhabit, so it seems likely that viewing distance relative to picture height has reduced sharply. This effect coupled with the more immersive nature of HDTV means that film marks have a distinctly undesirable impact on viewing pleasure.



This family of artefact can have a number of different origins but share the same important characteristic that they are present in a particular form and location for a single film frame only. For this reason they will appear and disappear as flashes of high contrast and will often catch the viewer's eye. Although they can be colored if they are caused by partially scuffed film emulsion or have been subjected to color correction, they are normally white or black (depending on whether the obstruction was originally on negative or positive film).

## Picture Reconstruction

### 1) Photochemical Processing:

If the original camera negative (O-neg or OCN) of a film is available, it can be chemically cleaned to remove surface dirt and dust. This process typically consists of a chemical bath followed by hand wiping. The traditionally recommended solvent was 1-1-1 Trichloroethane (Trichlor) but in 1995 manufacture ceased due to its environmental impact. The Kodak website contains a list of alternatives which are currently in use, the most common being Perchloroethylene (Perc).

The chemical cleaning of film has the clear benefit of removing an artefact before it has been created so no picture reconstruction is required. It has been commonly used in film restorations including the first restoration of Star Wars in 1997 (twenty years after its original release in 1977). However, often the condition of the O-neg is such that photochemical techniques can be a risky business which could further damage or destroy the negative altogether. In fact often original camera negatives are simply not accessible and only inter-positive (IP) or inter-negative (IN) prints (or video tape masters) are available. In this case it is quite likely that the dirt or dust is printed into the film and can't be wiped away.

Of course, cleaning can only deal with alien objects on the surface of a film but there is also a photochemical process called wet-gate that can be used if the film is scratched. This method can be applied during optical film printing or telecine transfer and also uses Perchloroethylene. It is important to note that the wet-gate process doesn't repair damage to the film but simply hides its effect during transfer as the Perc has the same optical properties as the film. It is only effective if the acetate base or protection layer is scratched; it will not offer any benefit if the emulsion layer itself is damaged as this means that there has been a loss of real picture content. During transfer, the film is immersed in Perc and the solvent fills in the gap caused by the scratch making sure there is no deviation in refractive index to change the propagation direction of the light. This ensures that the scratch has minimal impact on the optical process and the resulting transfer is uncorrupted.

### 2) Digital Image Processing

Advances in digital image processing have opened the door to a wide range of techniques for image reconstruction. Unlike the photochemical techniques, this is a less pure approach as it doesn't retrieve 'lost' picture content but starts from the premise that an area of the picture is damaged irrevocably and must be recreated to prevent a negative impact on viewer experience.

In order to fill in the damaged area, image data from within the same film frame and from other frames in the sequence is analyzed to establish plausible replacement content. However, a mathematical match does not always lead to a convincing visual result and there are a number of challenges to look out for:

#### a) Image Resolution:

One of the key difficulties when reconstructing picture content is preserving resolution. Simple linear filtering techniques will always lead to a local softening of the picture and this is still a danger with more sophisticated median filters or cloning algorithms. As a general rule, spatial or 2D processing (reconstruction from data within the same frame) is more likely to suffer from a drop in resolution than temporal or 3D processing (reconstruction using data from other frames in the sequence, looking forwards and backwards in time).

b) **Motion:**

As you can imagine, rebuilding picture that contains moving objects is always very difficult without introducing blurring. The only way to achieve a high quality repair is to estimate the motion in the image and use this analysis along with temporal reconstruction to ensure the damaged area is replaced with credible picture information. As previously mentioned, temporal processing is a good way to maintain sharpness but when it fails it can introduce a different type of 'hard-edged' artefact that can be unpleasant.

c) **Grain Structure:**

To ensure authenticity is preserved, a repair must not significantly change the visible grain structure of the original film. A classic example is an algorithm that repairs a film mark but completely removes grain within the reconstructed area making it stand out as different from the rest of the image. It is also important to ensure that repairs do not introduce artificial texture or patterning that can make the result appear very 'digital' and 'processed'.

It is critically important to remember that although the damage exists in a single film frame, the restoration is of an entire sequence of moving pictures. Often an apparently seamless repair when looking at a still image can be unpleasantly obvious when watching back the sequence as moving objects move in and out of the repaired area and temporal continuity is not maintained.

There are many different mathematical algorithms which have been developed for the purpose of image reconstruction. Broadly they split into two groups: guided and unguided repair.

**Guided Repair**

Guided repair requires a pre-processing stage during which an operator identifies the areas of a film frame that need reconstruction. This ensures that repairs are always correctly targeted at damaged picture and so removes any risk that processing will be applied to undamaged content. However, this human intervention is costly in operator time. Remember that a two hour movie will contain 172,800 film frames!

By its very nature, guided repair is not a real-time approach (one minute of film takes longer than a minute to process). It is normally undertaken using software tools running on high specification IT equipment although it may use hardware acceleration (such as a dedicated plug-in graphics card) to speed up the generation of results depending on the complexity of the processing required. Many different solutions are commercially available and are collectively referred to as 'paint' tools or 'in-painting'. In-painting is a term that covers a range of techniques for the cloning of picture samples to in-fill an unwanted area of the image. Texture synthesis is also used to ensure grain structure is preserved. Results vary but can be incredibly impressive. The main drawback is the operator-intensive nature of the process which adds significantly to the cost of restoration.

**Unguided Repair**

Unguided repair attempts to automatically detect regions of an image that need attention and reconstruct them accordingly. This now requires two complex mathematical algorithms: one for artefact detection and one for picture reconstruction. Automatic detection offers a huge benefit in reduced operator time but needs to be of a very high standard to ensure there are a minimum number of false-positives (unnecessary repairing of undamaged picture regions) and false-negatives (missed artefacts left unrepaired).

There are dedicated hardware products as well as software solutions available for unguided repair. Dedicated hardware will guarantee real-time processing but as these solutions do not use standard IT equipment they often have a higher up-front cost of ownership. Of course, the real cost depends upon the business return that can be generated from a restoration solution and here the relative benefits of real-time and non-real-time processing must be weighed up.

Snell's Archangel Ph.C-HD real-time hardware solution tackles the problem of film mark detection and repair using a process called Phase Correlation Motion Estimation (Ph.CTM). This analyzes each film frame and calculates the direction and speed of travel of all moving objects. Once this analysis is complete, it is possible to project the likely content of the current film frame from the content of the frame before it and after it; this process is referred to as motion compensated projection. The two available projections (one forward in time and the other backward in time) can then be compared with the actual picture content of the current frame and the difference (allowing for slight errors due to certain algorithm limitations) gives an accurate representation of film dirt or damage. The motion compensated projections can then be used to create a true repair of the damaged region without any reduction in picture sharpness or blurring.

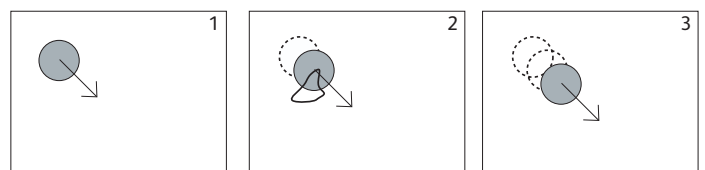


Figure 1: Three consecutive film frames with a moving object partially obscured by a film mark in the second frame.

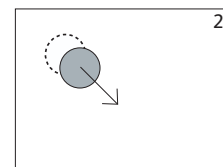


Figure 2: Motion-compensated projection of frame 2 from frames 1 and 3.

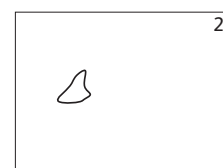


Figure 3: The difference between the projected second frame and the actual second frame is the film mark.

The final stage of the dirt repair process in Archangel Ph.C-HD analyzes the reconstructed film frame and assesses the impact of each film mark repair individually. Any repair that creates a hard-edge at its perimeter is judged to be a false-positive or a partial repair and is reverted. False-positives are considered less desirable than false-negatives as they affect original picture content.

#### IR Channel Dirt Map

It's possible to combine many of the benefits of guided and unguided film mark repair using the infra-red channel available from certain film scanners (for example the Scanity™ from Digital Film Technology). The result of the IR scan (if available) provides a map for the presence of scratches and dirt on the film surface and can be used to guide a reconstruction algorithm. This technique will not detect printed in marks and it is only available with some restoration solutions but it may become more common.

### Choosing the Right Solution

Whatever your reason for rescuing damaged material, whether you are restoring archive footage, re-purposing content or returning to film for a new Blu-ray or DVD release, identifying the right restoration solution will depend on a number of factors: the available time and budget, the condition of the material and how much treatment it needs, the result you are targeting and critically what restoration solutions and operator skills you have access to. The many different photochemical and digital solutions available can all play a part in achieving the right result and often the best approach is to select a mix of technology to establish a workflow that suits your project. For example, a real-time hardware solution can either be used as a standalone system for affordable restoration with a small number of content passes, or alternatively as a preliminary stage to safely remove a high percentage of artefacts reducing the cost of a subsequent frame by frame restoration leaving far fewer artefacts for an operator to manually identify and repair.

The possibilities are many and varied but it is important not to underestimate the benefits of well restored material. The techniques now available at an affordable price yield results that can make a huge difference to your content - both in terms of viewing quality and of course financial return.

Snell's Archangel Ph.C-HD real-time digital restoration system is the product of all Snell's knowledge and experience of restoration going back over ten years and covering participation in many European restoration projects such as BRAVA, AURORA and PrestoSpace, and more recently the restoration of one of the most watched documentaries ever made, the 1973 TV series The World at War, restored for release in HD on Blu-ray.

As a result we are confident that we can support the needs of a growing restoration market to deliver the highest quality picture content, which is after all, the goal of everyone involved in video and film restoration.

If you would like to discuss how Snell's Archangel Ph.C-HD could help with your latest restoration project, please contact your nearest Snell office or regional representative, or visit [snellgroup.com](http://snellgroup.com) for more information.

#### References

<http://inventors.about.com/od/pstartinventions/a/stilphotography.htm>  
<http://inventors.about.com/library/inventors/blmotionpictures.htm>  
[http://inventors.about.com/od/estartinventions/ss/George\\_Eastman.htm](http://inventors.about.com/od/estartinventions/ss/George_Eastman.htm)  
<http://inventors.about.com/library/inventors/bledison.htm>

[www.filmpreservation.org](http://www.filmpreservation.org)  
[http://en.wikipedia.org/wiki/Film\\_preservation](http://en.wikipedia.org/wiki/Film_preservation)

[http://en.wikipedia.org/wiki/Nitrate\\_film#Nitrate\\_film](http://en.wikipedia.org/wiki/Nitrate_film#Nitrate_film)  
[www.pictureshowman.com/articles\\_restprev\\_nitrate.cfm](http://www.pictureshowman.com/articles_restprev_nitrate.cfm)  
[www.glencinema.co.uk](http://www.glencinema.co.uk)  
[www.tcm.com/fan/](http://www.tcm.com/fan/)  
<http://secrethistoryofstarwars.com/savingstarwars.html>

[www.motion.kodak.com](http://www.motion.kodak.com)

[www.dft-film.com/scanners/scanity.php](http://www.dft-film.com/scanners/scanity.php)

[www.theworldatwar.com](http://www.theworldatwar.com)



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