Delivery Notification for

Deliverable D4.3 PPB3

Contactless playback tool for audio disks

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ABSTRACT	A working prototype for optical playback of audio records was developed by INA. The process has been patented. This prototype is innovative with respect to the already known optical recovery methods, in that it does not require costly photographic processes, or high-end imaging solutions. A very simple lighting apparatus is the key to the process, and allows the use of conventional imagery tools. An industrial version is under development by the new partner Indeep.
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1. Document Scope

The PrestoSpace project's objective is to provide technical solutions and integrated systems for digital preservation of all types of audiovisual collections. The project intends to provide tangible results in the domain of preservation, restoration, storage and archive management, content description, delivery and access. Economic factors supporting preservation services will be addressed. The principal aim is to prepare the way for preservation factories providing affordable services to all kinds of collection custodians in order to manage and to allow access to their assets.

Before the invention of the magnetic tape recorder in the early 50's, recording on discs was the only way to preserve audio information. National audio archives and radio stations have important collections of historical interest obtained by direct recording. There are millions of such disks, most of them unique, that are waiting on shelves for an efficient digitisation tool.

The specific focus of subtask 3 of WorkPackage 4 "playback devices" was to realise the prototype of a tool for optically reading analogue audio disk records. This document is a record of the delivery of this prototype.

2. Summary of Deliverable

Deliverable *D4.3 PPB3 Contactless playback tool for audio disks* is a prototype that is effectively able of playing back analogue monophonic disk records.

The physical assembly includes equipment for translating and rotating the disk, a specifically designed lighting device, a camera with its lens for acquiring the pictures. The construction is robust enough that the system can be transported.
The control and computing part includes power supplies and cabled logic, and a Linux based PC that grabs and processes the pictures from the camera to extract the audio information.

The design of the prototype is based on patented innovative designs (patent FR2874280, EP1626402, US2006044988).

The acquisition of a disc side is made in two steps : first a set of pictures organised in several rings is acquired, then the pictures are analysed and decoded into an audio .WAV file. One side of a disk (3 minutes) is acquired in one hour. The industrial versions of the system will run near real-time.

3. Notification of Delivery

The prototype was built during years 2005-2006, and demonstrated for the first time to the public during the PrestoSpace Training Session, Amsterdam, on 13-14/9/2006. Since then it has been shown during the AES France Days, on 30/11/2006. These presentations received a great interest.

The development of the prototype is continuing, and a new partner, Indeep, has started to develop an industrial version of the system, with a target of more than 30 deliveries, first deliveries expected end of 2007, before the end of the project.

4. Detailed Description of Deliverable

4.1. Preamble

The description hereafter reflects the status of the prototype at the time this document is written. The final product, even if based on the same underlying principles, will be very different in look and feel, and provide superior performances in terms of speed, and quality of the results.

4.2. The optical playback principle

The engraved groove was obtained by the action of a fixed shape cutter on a blank disk. This produced a V shape, composed of two walls, oriented at about 45 degrees of the surface of the disk. The (monophonic) audio signal is represented on the disk by the lateral speed.

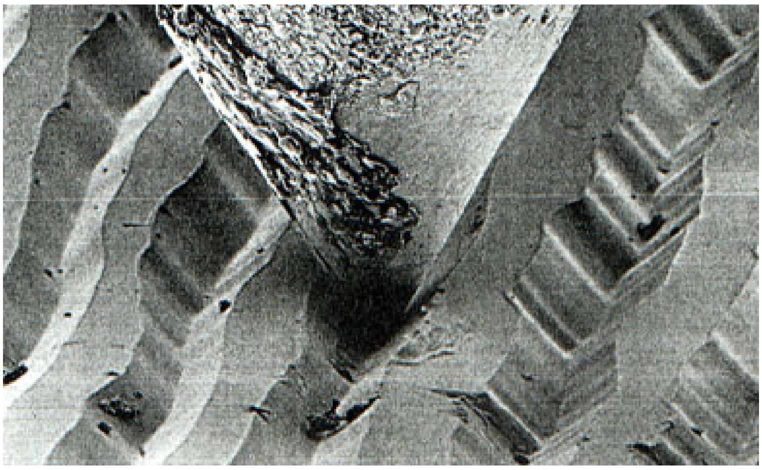

Figure 1 : an extreme closeup on the groove structure

source of the picture : unknown author
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http://perso.orange.fr/dj-issssalop/microsillon%2520(DJ%2520Issssalop%27).jpg

The underlying principle is to exploit the specular reflection on the groove walls.
In the system, an area of the disk is illuminated by a distribution of coloured rays, the colour depending on the direction of arrival. Through reflection on the groove walls, at each point of the lighted area, one direction (one colour) is selected (reflected) towards a camera. The obtained images are direct colour-coded sections of the audio signal. Several grooves are captured in one rotation of the disk with multiple images, forming a ring. These angles can be measured on an extended area of the record, typically 2x2mm, making groove tracking superfluous in the digitisation phase.

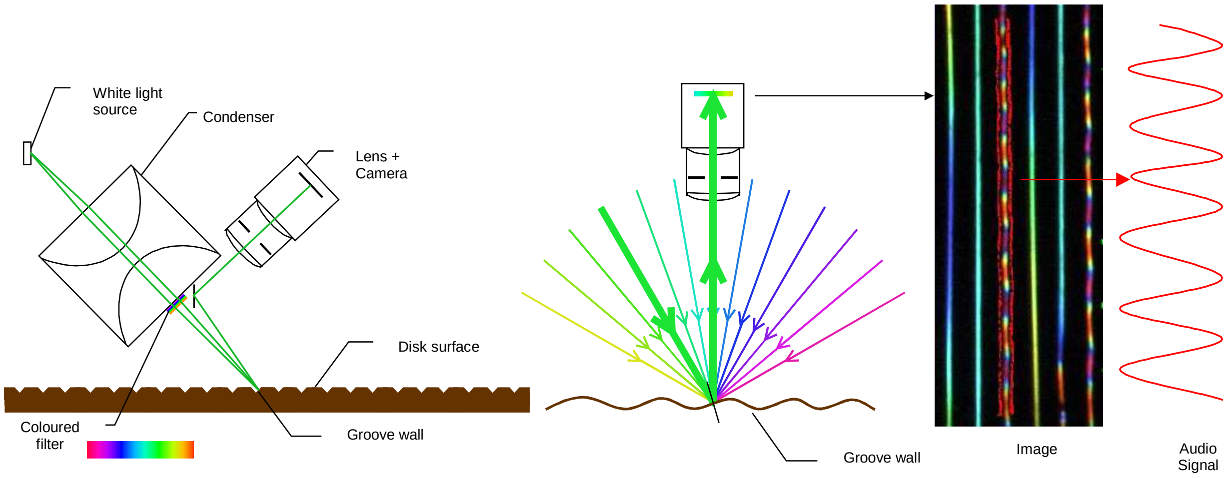

Figure 2 : The optical playback principle

4.3. The acquisition system

4.3.1. The Physical implementation

The physical implementation is made of a robust metal structure where the adjustments could be easily obtained. Most of the common adjustments (angulation, focus) are made through the knob at the top of the device.

Figure 3 : General view of the acquisition system

There are two motors : the first one allows rotating the disk so that the analysed area covers one ring. The second (translation) motor allows shifting the disk so that a new ring can be acquired. A "parking" position allows shifting the platter in a position such that the disk can be safely manipulated.

4.3.2. Lighting system

Figure 4 : A Closer view of the Condenser

The lighting system uses a white source LED, that is fed to a condenser made of two aspheric lenses, and that focuses the source on a small area on the disk, with an approximate incidence angle of 45 degrees. On the light path is added a transparent mask with a colour running across the complete colour range.

4.3.3. The Lens and Camera

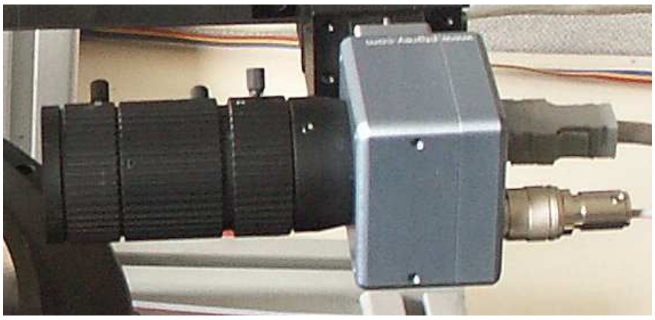

Figure 5 : The lens and camera

The lens is a zoom, mounted on a CCD camera, that allows to acquire 400x400 pictures at 3 to 5 microns per pixel. A small mirror (12x12mm) reflects the images towards the camera. The camera delivers the pictures through FireWire link to the computer.

4.3.4. The electronic case and power supply

All the power and logic for driving the motors (translation/rotation) are enclosed in the same case. This case also contains an electronic board that allows controlling the motion, triggering the camera, and flashing the light source synchronously.

4.3.5. The computing system

The computing system is a Linux PC that performs the following functions :

- Providing an interface to the motors and to the camera, allowing an interactive setup of the acquisition. This is done through a customised version of the Coriander software.
- Acquiring the pictures from the Camera (several rings of pictures can be acquired in batch mode).
- Processing the pictures to extract the signal and produce the audio file.
- Providing an interface to the user through the Audacity software to post-compensate the audio files, and sound playback.

4.4. The picture processing

The images obtained with the system are similar to this one. On the prototype, there are 2250 pictures per ring, 40 rings per disk. On this picture the modulation is clearly visible, from purple to yellow. Green is the mean (zero) signal value. Some darker spots are clearly visible on the picture, but they can be detected in software, and the missing values are interpolated.

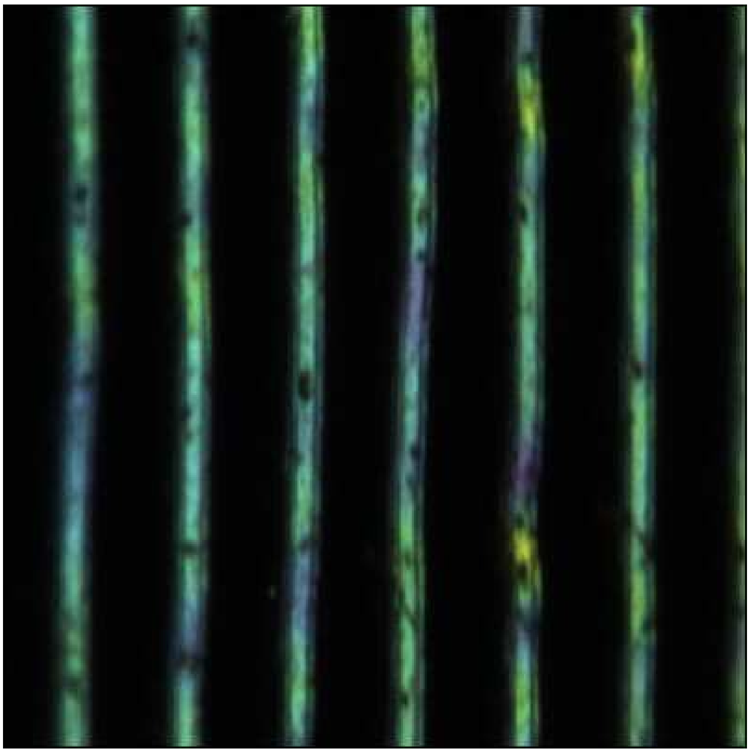

Figure 6 : A typical picture before processing

Image processing is used to reassemble the pictures into continuous rings, track the grooves, detect the position of dust and scratches, and measure the signal values. This information is then averaged into a very high frequency (typically higher than 200kHz) signal and the associated confidence level. Autoregressive methods are used to interpolate the signal when confidence is low. The resulting signal is then translated into an audio .WAV file. The suitable post-compensation process is applied at a later stage within the Audacity Open Source Audio editing software.

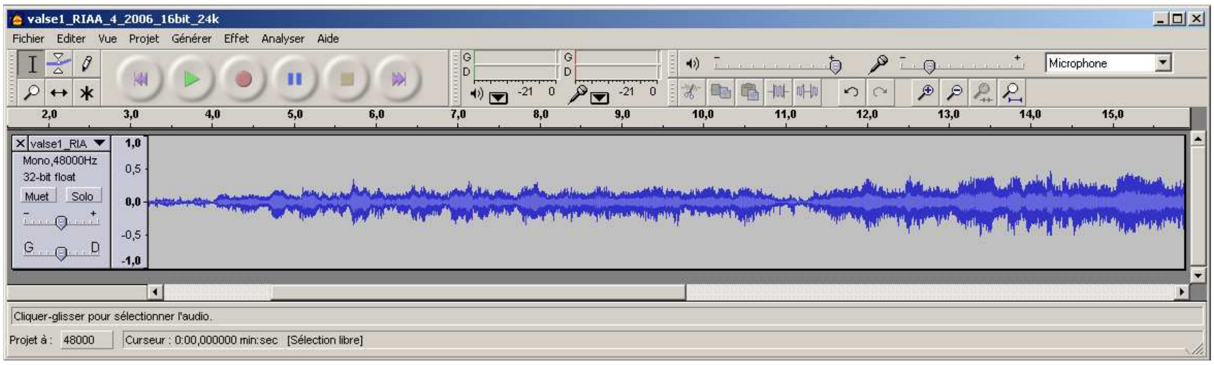

Figure 7 : A sample of the recovered sound

4.5. Performances of the optical playback system

The system has up to now exhibited performances that are comparable to existing playback systems for audio disks.

On clean reference disks, the SNR has been measured around 60dB, bandwidth is well over 15kHz, and THD+Noise is around 1%, but can still be improved through a suitable compensation of some inherent non-linearities within the chain (coloured mask printing, among others).

It is expected that when the dust correction software is fully functional, the performances will be much higher than conventional playback, since correction will be made from the dust position, instead of the blind de-clicking approach of common use.

The process has been tested and proved to be applicable to a wide range of other kinds of disks, for example Pathé sapphire disks and Berliner.
It is also able of reading 33rpm Vinyls, although digitising stereo recordings would require scanning both groove walls. This can be done using the same system, but a complete demonstration of this process has not been made up to now.

It is planned to develop specific software processing of the pictures, to allow the recovery of the signal from disks with cracked.

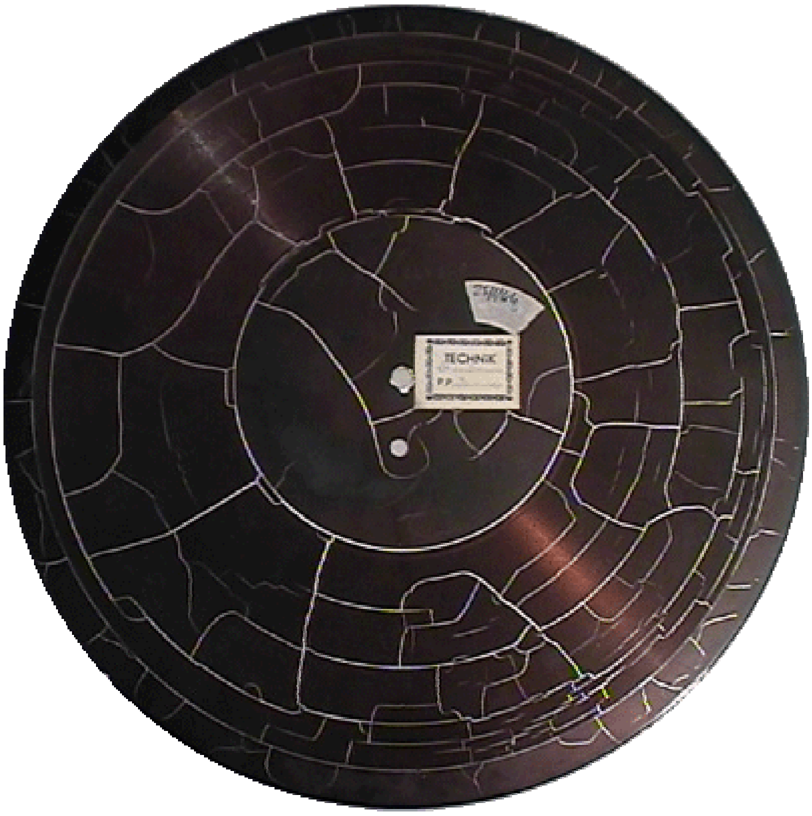

Figure 8 : A disk with lacquer cracks

The advantages of the optical playback system are :

- No contact with the groove, simple setup
- Simple and affordable technology
- A wide range of disks can be read
- Good performances in terms of signal quality
- All the height of the groove wall can be read : high robustness to dust, therefore lower need for disk cleanup before playback.
- Potential recovery of cracked disks

Drawbacks are currently :

- The system is currently slow : more that 1 hour is necessary for digitising a 3 minutes disk side
- The system is currently monophonic.

It is planned to achieve good improvements on the two points above in the industrial version of the system.

5. Status of developments

The Prototype is still evolving. Since September 2006, A new partner, Indeep, has joined the PrestoSpace project with the sole objective of finalising the developments and to launch a commercial device based on the same principles by the end of 2007.

The current developments that are taking place are :

- Designing a new lighting system (condenser) with a wider aperture (up to 144 degrees, to cover the whole dynamic range).
- Finalising the dust and occlusion correction software
- Developing a specific algorithm for playing back the cracked lacquer disks
- Developing the new physical system.
- Developing the software for the new system.

6. Related Documents and Links

Public documents :

The design has been patented (patents FR2874280, EP1626402, US2006044988). These patents are accessible at the following address :
http://v3.espacenet.com/textdoc?CY=ep&LG=EN&F=4&IDX=FR2874280&DB=EPODOC

The text of the Call that led to the selection of Indeep as the industrial partner for the development of the system is still available on the PrestoSpace public web site :
http://prestospace.org/Call/Pspace_Call2_disks_1.0.pdf

Louis Laborelli, Jean-Hugues Chenot, and Alain Perrier, "Non contact Phonographic disks digitisation using structured colour illumination", proceedings of AES 122nd Convention - Vienna 5-8/5/2007.

Louis Laborelli, Jean-Hugues Chenot, "Dust Detection by Colour Analysis in an Optical of Phonographic Disks Digitisation". Proceedings of ICIP 2007 (IEEE International Conference on Image Processing, San Antonio, 16-19/9/2007)

7. Glossary

Term	Description
78 rpm	78 rotations per minute
Audacity	An open source software for recording and editing sounds. It is available for Mac OS X, Microsoft Windows, GNU/Linux, and other operating systems, and is available at http://audacity.sourceforge.net/
Berliner	Early disk recordings manufactured by Emile Berliner starting in 1893. Used a lateral modulation.
Coriander	An open source graphical user interface software for IEEE1394, IIDC-compliant digital cameras. It includes camera control, video display, saving, FTP and V4L export. It is available at http://sourceforge.net/projects/coriander
Direct cut	Recordings that were engraved using a specific machine, for example Neumann. Most of the remaining early radio stations recordings were made as Direct cut disks (3 minutes per side)
Lacquer	Common denomination for disks with an aluminium base plate coated with a lacquer composed primarily of cellulose nitrate (usually misidentified as "acetate.")
Lacquer cracks	On some lacquer disks, shrinkage of the lacquer causes cracks to appear and leave the aluminium visible between the patches.
Pyral	The French company that produced lacquer disks ("Pyrals").
Pathé (Sapphire)	Early disk recordings manufactured by Charles and Emile Pathé between 1904 and 1930. Used a vertical modulation.
Shellac	Laminated pressed 78 rpm disks, in production up to 1950, when it was definitely replaced by Vinyls
Vinyls	Non-laminated pressed commercial disks. Exist in 78, 45, and 33 rotations per minute.