LINUX AUDIO CONFERENCE 2010 UTRECHT THE LAC TIMES Dear reader, the main outline for the program of the LAC 2010 is defined and most presentations, workshops, installations and music have found a place in the timetable. In this edition of the LAC Times most program elements such as paper presentations, workshops, installations and the evening programme are shown. With still a month to go, some changes can not be avoided but overall the programme is pretty stable. In the last edition of the LAC Times, to appear at the end of April, we will publish the definitive programme and time table, which will then also be available on the website. I've listed the activities per day, so if for some reason you can't attend the entire conference, you can use this as a guide to select which days are most interesting to you. See you all in May! - Marc Groenewegen **Topics in this edition:** A first glimpse of the LAC 2010 programme ■ The 150-Years-of-Music-Technology Composition Competition A short history of recording sound [part 2] A FIRST GLIMPSE OF THE LAC 2010 PROGRAMME Saturday May 1 Papers & presentations Workshops **QuteCsound, a Csound Frontend** - Andrès Cabrera **Developing parallel audio applications with FAUST** - Yann Orlarey While the number of cores of our CPUs is expected to double every new QuteCsound is a front-end application for Csound written using the Qt toolkit. It has been developed since 2008, and is now part of the Csound generation, writing efficient parallel applications that can benefit from all these cores, remain a complex and highly technical task. The problem is distribution for Windows and OS X. It is a code editor for Csound, and even more complex for real-time audio applications that require low latenprovides many features for real-time control of the Csound engine, cies and thus relatively fine-grained parallelism. through graphical control interfaces and live score processing. In order to facilitate the development of parallel audio application, the FAUST compiler developed at GRAME provides two powerful options to Implementing a Polyphonic MIDI Software Synthesizer using Corouautomatically produce parallel code. The first one is based on the OpenMP tines, Realtime Garbage Collection, Closures, Coroutine-local Variables and Dynamic Scoping - Kjetil Matheussen standard, while the second one uses Posix pthreads directly. This hands on demo will give the audience the opportunity to discover these parallelization facilities, their limits and their benefits, on concrete examples of This paper demonstrates a few programming techniques for low-latency sample-by-sample audio programming. Some of them have most likely audio applications. not been used for this purpose before. The demonstrated techniques are: Realtime memory allocation, real-time garbage collector, storing instru-A bird's-eye view on Linux Audio part I - Lieven Moors ment data implicitly in closures, coroutine-local variables, and handling signal buses using dynamic scoping. A comprehensive overview of Linux Audio and other Open Source Music Applications with several live music demos. Interesting for beginners as Writing Audio Applications using GStreamer - Stefan Kost well as advanced users. A bird's-eye view on Linux Audio part II - Lieven Moors GStreamer is mostly known for its use in media players. Although the API and the plugin collection has much to offer for audio composing and A comprehensive overview of Linux Audio and other Open Source Music editing applications as well. This paper introduces the framework, focusing on features interesting for audio processing applications. The author Applications with several live music demos. Interesting for beginners as reports about practical experience of using GStreamer inside the Buzztard well as advanced users. project. Emulating a Combo Organ Using Faust - Sampo Savolainen This paper describes the working principles of a 40 year old transistor organ and how it is emulated with software. The emulation presented in this paper is open source and written in a functional language called Faust. The architecture of the organ proved to be challenging for Faust. The process of writing this emulation highlighted some of Faust's strengths and helped identify ways to improve the language. LuaAV: Extensibility and Heterogeneity for Audiovisual Computing -Graham Wakefield We describe LuaAV, a runtime library and application which extends the Lua programming language to support computational composition of temporal, sound, visual, spatial and other elements. In this paper we document how we have attempted to maintain several core principles of Lua itself - extensibility, meta-mechanisms, efficiency, portability - while dealing with the complex temporal demands of flexibility and accuracy inherent to the context of audio-visual interactive media arts and research. Code generation is noted as a recurrent strategy for increasingly dynamic and extensible environments. The WFS system at La Casa del Suono, Parma - Fons Adriaensen At the start of 2009 a 189-channel Wave Field Synthesis system was installed at the Casa del Suono in Parma, Italy. All audio and control processing required to run the system is performed by four Linux machines. The software used is a mix of standard Linux audio applications and some new ones developed specially for this installation. This paper discusses the main technical issues involved, including sections on the audio hardware, the digital signal processing algorithms, and the software used to control and manage the system. **Pro Audio is Easy, Consumer Audio is Hard** - Lennart Poettering Audio Production and consumer audio share a lot of infrastructure -- however there are a number of major differences. While for audio production environments reliable low latencies are key, dynamic reconfigurable routing unimportant and power management irrelevant, for consumer audio (i.e. desktop and mobile), latencies and routing must be dynamically reconfigurable and power consumption minimized. This has the effect that a good consumer audio stack must adjust much more dynamically, flexibly and seamlessly to its current workload than a pro audio stack. Buffer sizes/latencies (up to 2s!) must be changed dynamically, the whole audio pipeline must be able to "rewind" its playback position if needed so that long buffers do not result in slow reaction to user input, and unreliable clients with different latency requirements must be handled at the same time. This makes it necessary to leave the limited domain of the sound card clock and schedule audio with the system clock, which of course

adds major complexities due to the required estimation of deviation. additional complexities.

Hence one can argue that while an idealized pro audio stack could be modelled as a set of one-way fixed-speed FIFO buffers, a consumer audio stack needs to be modelled as buffers that can be rewound, dynamically changed in size and run with varying speeds, in addition to many other In this talk I hope to explain a little how the consumer audio stack works,

how it is different from the pro audio stack, where the complexities are, where we can share technology, where we cannot, where we should, and

Of course, the title of this talk is a bit exaggerated to catch your attention. However, there's some truth to it, and in this talk you might hopefully

Lennart Poettering works for Red Hat's desktop group and is to blame ;-)

General-purpose Ambisonic playback systems for electroacoustic

Concerts of electroacoustic music usually feature works written for vari-

ous speaker layouts. Except in the most luxurious of circumstances, this

implies compromises in placement, frequent interruptions of the concert experience to relocate speakers, and/or errorprone equipment rewiring

or reconfiguration during the concert. To overcome this, an Ambisonic

concerts - a practical approach - Jörn Nettingsmeier

Workshops

Supercollider beginners - Jan Trutzschler, Marije Baalman

Supercollider advanced - Jan Trutzschler, Marije Baalman

covering specific advanced topics. Topics could include:

* Extending SuperCollider (writing your own classes)

* Input and output to devices or other programs

SuperCollider has been up and running on Linux since shortly after it was

released as open source software. In the past two years, it has become

really easy to install on Linux, and is packaged in distributions such as

For more advanced users of SuperCollider we offer another workshop

* Patterns (a different paradigm of composing based on musical sequen-

For this workshop, please sign up, and let us know what topics you would

Using ambisonics as a production format in ardour - Jörn Nettings-

An expert group performs a comparative study of several sound proces-

sing tools. Tools possibly included in the study: Pure Data, Supercollider, CSound, ChucK, FAUST, CLAM, Nyquist, Common Music and Fluxa.

A session on the Chuck programming language. How a more intimate familiarity with the workings behind synthesis can increase our options and

how a DIY approach to instruments may force us to think more deeply

about what we ourselves want, musically (as opposed to what's offered

A workshop introducing Campcaster, an open source radio management application for use by both small and large radio stations (yes, real radio

Learn the first steps of operating a radio station, including scheduling, live

through hardware set-ups, software installations and studio configurations, resulting in the creation of a fully-functioning Linux Audio Conference

The workshop will be led by Micz Flor and Adam Thomas, key members

behind Campcaster, which has been developing open source solutions for

Requirements: Ideally, but not essentially, participants should bring their

Campcaster packages are available for Debian and Ubuntu (Lucid and

Composition Competition - Than van Nispen tot Pannerden

of Sourcefabric. Sourcefabric is a new organisation formed by the team

independent media in developing countries for more than 10 years.

studio broadcast, play-out and even remote automation and networking via the web, all using free software. The workshop will take participants

PlanetCCRMA and Pure: Dyne. On Linux there is a choice between three

Take the first steps in SuperCollider!

editors: emacs, vim and gedit.

* Livecoding with SuperCollider

* Using the JITLib

like to see covered.

Other activities

Tools - Yann Orlarey

Workshops

Chuck - Kassen

commercially).

station.

Links:

Number of places: 8

own laptop with Linux installed

* http://www.sourcefabric.org

Key Signing II - Robin Gareus

Workshops

running Csound process.

using Creative Commons.

Installations

others.

Jury

Prizes

During the day several installations can be seen, heard, admired and in

Madjid Tahriri, Victor Valentim, Olaf Hochhertz, Louigi Verona and

Another submission possibility is by sending a link by e-mail (to lac@linuxaudio.org), but has an earlier deadline (26th of April).

lity of the use of the sample material

cation of Open Source Software

production and composition

- Patrick Feaster, a member of firstsounds.org, focusing on the origina-

- Marc Groenewegen, organiser of the LAC2010, focusing on the appli-

Hugo Verweij, teacher at the Utrecht School of the Arts, focusing on the

- Tonehammer has offered to sponsor a suitable prize for the winner in the neighborhood of \$79-100, drawing from the SFZ-compatible Toneham-

mer and Microhammer content. The winner's composition will also be

posted on the Tonehammer Phonautograms page, as a second demo and on the firstsound.org webpage as winner of this composition competition.

- The 1st, 2nd and 3rd prize compositions will be presented on the 3rd of

May at the Linux Audio Conference 2010 evening programme.

- Several other prizes can be won, but will be presented later.

* Free Tonehammer Sample Pack link:

http://www.tonehammer.com/?p=2393

nology was used for a consumer

format, Digital Audio Tape (DAT),

but was a failure in the consumer-

audio field (too expensive, too fi-

nicky, and crippled by anti-copying

regulations). DAT became popular

in studios (particularly home stu-

Within a few years after the intro-

duction of digital recording, mul-

titrack recorders (using stationary heads) were being produced for use

In the early 1990s, relatively low-

priced multitrack digital recorders

were introduced for use in home

studios; they returned to recording

on videotape. The most notable of

this type of recorder is the ADAT.

leased in 1991, the ADAT machine

is capable of recording 8 tracks of

digital audio onto a single S-VHS

is still a very common fixture in

professional and home studios

video cassette. The ADAT machine

Developed by Alesis and first re-

dios) and radio stations.

in professional studios.

- Than van Nispen tot Pannerden, member of the Muziekinstituut

MultiMedia (MiMM), focusing on the composition

some cases even played with thanks to contributions by Tim Blechmann,

Creative Commons - Björn Wijers

Live Coding with QuteCsound - Andrès Cabrera

This workshop will explore the Live Coding capabilities of QuteCsound

for generating score events for a running instance of Csound, through the

sing of note events to be generated, transformed, sent live, or looped for a

Be informed about the options and implications for licensing your work

use of the Live Event Panel and the QuteSheet python API. It will show how the QuteCsound frontend can serve as a python IDE for the proces-

* http://campcaster.campware.org/

Karmic) at http://robin.linuxaudio.org/deb/

For a description: see elsewhere in this edition

Making Waves - Micz Flor, Adam Thomas

stations, not internet radio) to schedule radio shows.

Key Signing I - Robin Gareus

The outcome is presented later that day.

where we shouldn't.

learn why I believe that.

Sunday May 2

Papers & presentations

for stuff like PulseAudio and more.

higherorder playback system can be used to create virtual speakers at any position as mandated by the compositions. As a bonus, the performer can then be given realtime control of the source positions in addition to their levels, increasing the creative freedom of live sound diffusion. Deployments at LAC 2009 and the 2009 DEGEM concert at musikFabrik in Cologne have yielded very good results and been met with general approval. More detailed listening tests are scheduled and will be reported upon. How the Real-Time Kernel Helps Audio and Video Applications - John Kacur Many of the Linux Distributions that are dedicated to audio and video make use of the Linux realtime kernel. This paper explores some of the advantages and disadvantage of using real time. It explains how the realtime kernel achieves lowlatency and shows how userspace can take ad-

vantage of realtime capabilities. This talk is presented by one of the realtime kernel programmers, and gives an overview of the realtime kernel for audio and video. **Indonesian Gamelan / Creative Commons -** *Maarten Brinkerink* A presentation about restoring traditional Indonesian folk music and Gamelan in particular. Algorithmic Composition - Joachim Heintz

Re-Generating Stockhausen's "Studie II" in Csound. A Study About Stockhausen's "Studie II" (1954) is one of the classical works of electronic music. Written at a time when Computers played no role in the production of sound, it exhibits a way of composing which is quite similar to programming. This can be shown by re-programming the complete piece just with the input of five numbers. Beside this reduction - which is made in Csound - the compositorial decisions come to the fore, showing a flexibility and variability of algorithms which can be inspiring and challenging

still today. Using open source music software to teach live electronics in pre-college music education - Hans Roels A basic course of live electronics is needed in pre-college music education to enable children to learn how to perform on a digital musical instrument. This paper describes the basic components of such a live electronic

course, examines whether open source music software is suited to realize these components and finally presents Abunch, a library in Pure Data created by the author, as a solution for the potential educational disadvantages of open source music software. **Education on music and technology** - Jeroen van Iterson, Marcel Wierckx, Marc Groenewegen We describe the development and the maintenance of a program for a professional education at the Utrecht School of Music and Technology. The program covers most of the field and offers various degrees up to PhD level. The program was developed over the last 23 years and is updated on a yearly basis. We deliver about 80 graduates every year to work, survive

and keep up with developments. 92 % of our students develop a healthy career after graduation. Music technology as a field of studies is in constant and rapid development and because of that the characteristics of the professional in the field are changing very rapidly too. For this reason we have built in mechanisms to enforce regular updates of the program and to

develop the knowledge and skills of the teaching staff. **Open Media / Creative Commons -** *Björn Wijers* **Monday May 3 Papers & presentations** Field Report: A pop production in Ambisonics - Jörn Nettingsmeier

This paper describes a pop production in mixed-order Ambisonics, with

an ambient sound field recording augmented with spot microphones pan-

toolchain, a number of miking and blending techniques will be discussed, geared towards the capturing (or faking of) subtle natural ambience and

good imaging. I will then describe the expected struggle to make the re-

pleasant sound stage and as much dynamics as possible.

blance - Marije Baalman

(BSP) technique.

Lopez-Lezcano

ned development.

rich representations are necessary.

sulting mix loud enough for commercial use while retaining a natural and

5 years of using SuperCollider in real-time interactive performances and installations - retrospective analysis of Schwelle, Chronotopia and Sem-

ned in third order. After a brief introduction to the hard- and software

Collaborative, interactive performances and installations are a challenging coding environment. SuperCollider is an especially flexible audio programming language suitable to use in this context; and in this paper I will reflect on 5 years of working with this language in three professional projects, involving dance and interactive environments. I will discuss the needs and context of each project, common problems encountered and the solutions as I have implemented them for each project, as well as the resulting tools that have been published online. Applications of Blocked Signal Processing (BSP) in Pd - Frank Barknecht

Sample processing in Pure Data generally is block-based, while control or

message data are computed one by one. Block computation in Pd can be suspended or blocked to save CPU cycles. Such "blocked signals" can be

used as an optimization technique for computation of control data. This paper explores possible applications for this "Blocked Signal Processing"

OrchestralLily: A Package for ProfessINSERT INTO activity (with

LilyPond and LaTeX - Reinhold Kainhofer

LilyPond [Nienhuys and et al., 2010] and LaTeX provide excellent free tools to produce professional music scores ready for print and sale. Here we present the OrchestralLily package for LilyPond, which simplifies the creation of professional music scores with LilyPond and LaTeX even further. All scores are generated on-the-fly without the need to manually specify the structure for each individual score or part. Additionally, a La-TeX package for the prefatory matter is available and a templates system to create all files needed for a full edition is implemented. **Term Rewriting Extension for the Faust Programming Language** - Albert Gräf

This paper discusses a term rewriting extension for the functional signal processing language Faust. The extension equips Faust with a hygienic macro processing facility. Faust macros can be used to define complicated, parameterized block diagrams, and perform arbitrary symbolic manipulations of block diagrams. Thus they make it easier to create elaborate signal processor specifications involving many complicated components.

16 speakers (4 hang from the ceiling, 8 surround the listening area at ear level and 4 more are below an acoustically transparent grid floor). We found that a standard commercial digital mixer was not the best interface for using the studio. Digital mixers are complex, have an opaque interface and they are usually geared towards mixdown to stereo instead of efficiently routing many input and output channels. We have replaced

Openmixer: a routing mixer for multichannel studios - Fernando

The Listening Room at CCRMA, Stanford University is a 3D studio with

the mixer with a dedicated computer running Openmixer, an open source custom program designed to mix and route many input channels into the multichannel speaker array available in the Listening Room. This paper will describe Openmixer, its motivations, current status and future plan-

The structure of the Open Sound Control (OSC) content format is introdu-

ced with historical con- text. The needs for temporal synchronization and dynamic range of audio control data are described in terms of accuracy, precision, bit-depth, bit-rate, and sampling frequency. Specific details are given for the case of instrumental gesture control, spa-tial audio control and synthesis algorithm control. The consideration of various transport mechanisms used with OSC is discussed for datagram, serial and isochronous modes. A summary of design approaches for describing audio control data is shown, and the case is argued that multi-layered information-

Best Practices for Open Sound Control - Andrew Schmeder

Tuesday May 4 Papers & presentations **Supernova** - Tim Blechmann SuperCollider [McCartney, 1996] is a modular computer music system, based on an object-oriented real-time scripting language and a standalone

synthesis server. supernova is a new implementation of the SuperCollider

synthesis server, providing an extension for multi-threaded signal proces-

sing. With adding one class to the SuperCollider class library, the parallel

signal processing capabilities are exposed to the user. Work Stealing Scheduler for Automatic Parallelization in Faust -Stephane Letz Faust 0.9.10 introduces an alternative to OpenMP based parallel code generation using on a Work Stealing Scheduler and explicit management of worker threads. This paper explains the new option and presents some benchmarks.

A MusicXML Test Suite and a Discussion of Issues in MusicXML 2.0 - Reinhold Kainhofer MusicXML [Recordare LLC, 2010] has become one of the standard interchange formats for music data. While a specification in the form of some DTD files with comments for each element and equivalently in the form of XML Schemas is available, no representative archive of MusicXML unit test files has been available for testing purposes. Here, we present such an extensive suite of MusicXML unit tests [Kainhofer, 2009]. Although originally intended for regression-testing the musicxml2ly con-

verter, it has turned into a general MusicXML test suite consisting of more than 120 MusicXML test files, each checking one particular aspect of the MusicXML specification. During the creation of the test suite, several shortcomings in the MusicXML specification were detected and are discussed in the second part of this article. We also discuss the obstacles encountered when trying to convert MusicXML data files to the LilyPond [Nienhuys and et al., 2010] format. 3DEV: A tool for the control of multiple directional sound source trajectories in a 3D space

- Esteban Calcagno This Paper presents a GNU software (3DEV) developed for the creation, transformation and temporal coordination of multiple directional sound source trajectories in a three-dimensional space. 3DEV was conceived as a general tool to be used in electroacoustic music composition, and the data generated by it may be transmitted on a simple and effective way to several spatialisation programs. Sense/Stage - low cost, open source wireless sensor and data sharing infrastructure for live performance and interactive realtime environments -Marije Baalman

SenseStage is a research-creation project to develop a wireless sensor network infrastructure for live performance and interactive, real-time environments. The project is motivated by the economic and technical constraints of live performance contexts and the lack of existing tools for

artistic work with wireless sensing platforms. The development is situated within professional artistic contexts and tested in real world scenarios. In this paper we discuss our choice of wireless platform, the design of the hardware and firmware for the wireless nodes, and the software integration of the wireless platform with popular media programming environments by means of a data sharing network. **Evening programme Concerts and other performances** Every night from May 1 till May 3 there is an evening programme.

Due to the rent of the locations these concerts are not entirely free. Admission fees will be around 7 Euros. Saturday May 1 - Multimedia Event @ MediaLab Saturday kicks off with an informal event with Louigi Verona, Miguel Negrão, Lovis and more. Sunday May 2 - Concert @ Kikker

The cozy Kikker Theater hosts the LAC concert for this year with works by a.o. Fernando Lopez-Lezcano, Jonas Foerster, Madjid Tahriri, Massimo Carlentini, Yota Morimoto, Frances-Marie Uitti and Augusto Meijer.

The night you've all been waiting for is taking place in the SJU basement with two stages bringing music, performance and lots of live coding. Contributions by Marc Sciglimpaglia, Malte Steiner, Marije Baalman, Wanda&Nova, Rutger Muller and more. **Poster** During the conference there will be a large room where you can put up a poster showing your work or drawing attention to a subject you would

like to get feedback on, discuss about or find assistance (e.g. co-developers) for. During the programme there is ample time to have a coffee and

Monday May 3 - Linux Sound Night a.k.a. Club Night @ SJU

Posters can be any size up to A2. THE 150-YEARS-OF-MUSIC-TECHNOLOGY COMPOSITION COMPETITION As could be read in "A short history of recording sound part 1", published in the first edition of The LAC Times, the oldest reproduced sound

wander around.

fragment dated from 1860: exactly 150 years ago. This sample is a transcript from the 1860 'Au Claire de la Lune' phonautograph recording, by Édouard-Scott de Martinville himself. For this anniversary of 150 years of audible Music Technology a composition competition is organised. The Linux Audio Conference 2010, in collaboration with the Utrecht

School of the Arts and Firstsounds.org, announces the 150-Years-of-Music-Technology Composition Competition. This competition is open to all composers of any nationality and age. About the competition The intention is that a new composition is made with the theme "150 years of recording sound". The original 150-year old "Au Claire de la Lune" sample, found at www.firstsounds.org/sounds/scott.php can be used as a starting point.

There is also a free Tonehammer sample package at which can be used. See below for the link*. For the composition process, the use of Linux and/or open source applications is strongly encouraged and appreciated The composition must be accompanied by a (short) description of the work and the use of software and technology

Composition submissions will be presented in stereo format (this is also necessary for the website-implementation). Compositions must be handed in on the first day of the conference: May 1 on a CD, DVD or be transferred from a memory stick. A SHORT HISTORY OF RECORDING SOUND [PART 2] gineers, who also discovered the In Part 1 we could, in short, read about the early beginnings of recortechnique of AC biasing, develoding sound since 1860, 150 years ped 2-track recording which led to the development of multitrack ago. recording. Much of this credit also

The invention of the phonautograph goes to guitarist, composer and was mentioned as the predecessor technician Les Paul, whose expeof Edison's phonograph. Electrical riments with tapes and recorders recording and its groundbreaking in the early 1950s led him to order revolution on sound recording the first custom-built eight-track were also elaborated on in this first recorder from Ampex. episode. In part 2 Magnetic and Digital recording are explained. **Magnetic recording** The magnetic recording was demonstrated in principle as early as 1898 by Valdemar Poulsen in his Telegraphone. Magnetic wire recor-**Digital recording**

ding, and its successor, magnetic

signal, which is analogous to the

sound that is to be recorded, is fed

pattern of magnetisation similar to

On the 1900 World Exposition in

Paris, Poulsen had the chance to

record the voice of Emperor Franz

Josef of Austria which happens to

be the oldest surviving magnetic

It was World War II, which was a

worldwide tragedy but also led to

a boom for the record industry as

well as the development of new

audio recording today.

to the recording head, inducing a

the signal.

tape recording, involve the use of a

magnetizable medium which moves past a recording head. An electrical

It was this multitrack tape-technology which enabled the development of the first quadraphonic sound, in which each of the four tracks was used to simulate a complete 360-degree surround sound. Digital audio uses digital signals for sound reproduction. This includes analog-to-digital conversion, digital-to-analog conversion, storage, and transmission. The first digital audio recorders were reel-to-reel decks introduced by companies such as Denon (1972), Soundstream (1979) and Mitsubishi. They used a digital technology known as PCM recor-Within a few years, however, many

studios were using devices that

a standard video signal, which

encoded the digital audio data into

was then recorded on a U-matic or

other videotape recorder, using the rotating-head technology that was

play back.

found here: http://creativecom- mons.org/licenses/by-nc-sa/3.0/nl Deze publicatie is uitgegeven onder een Creative Commons - Naams-

format, and legal issues involved in

copying such files, has driven most

of the innovation in music distribu-

tion since their introduction in the

As hard disk capacities and compu-

ter CPU speeds increased at the end

of the 1990s, hard disk recording

- Than van Nispen tot Pannerden

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became more popular.

late 1990s.

Author

around the world. vermelding-Niet-commercieel-In the consumer market, tapes and Gelijk delen 3.0 Nederland licentie. gramophones were largely dis-De volledige licentie is te vinden op: http://creativecommons.org/ placed by the compact disc (CD), which was introduced 1982 and a <u>licenses/by- nc-sa/3.0/nl/</u> lesser extent the minidisc. These recording media are fully digital and require complex electronics to Digital sound files can be stored on any computer storage medium. The development of the MP3 audio file