#### 7<sup>th</sup> International Congress on Sound and Vibration 4 – 7 July 2000 Garmisch-Partenkirchen, Germany

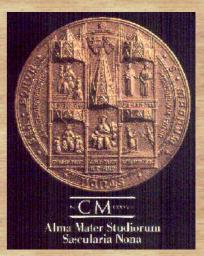


#### THE NATURAL TRUMPET AND ITS VIRTUAL SOUND

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# The mainframe:

 A) Virtual reconstruction of the sound quality of musical instruments.
 *Violins, trumpets, flutes*

B) Virtual reconstruction of spaces for music and speech.

Theatres, churches, auditoria

# **Introduction and Goals**

Restoration cultural heritage Storage museums

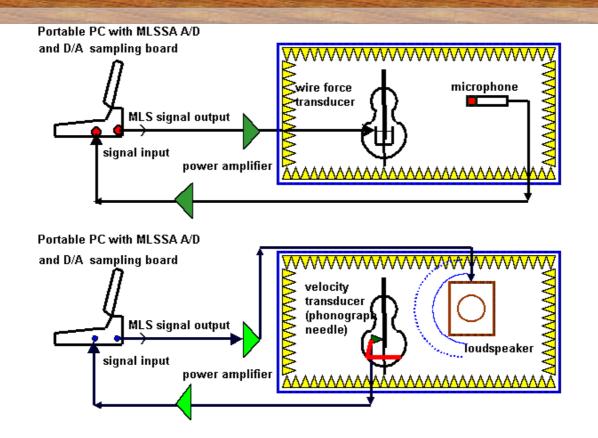
Sound and music: "visualisation" and "auralisation".

Multimediality and acoustics: could they live together?

# Previous experiments:

- → Evaluation of sound quality of sound chests in different violins
- Measurements of IR (force pressure) on the bridge
  - Calculation of inverse filter
- Recordings in anechoic chamber
- Deconvolution: rec \* F.I.R. (getting "dry" music)
- Convolution  $\longleftrightarrow$  virtual sound

# The violins (ISMA95, JNMR97)



Direct (up) and reciprocal (down) method of measurements

5/7/2000

# The Trumpets

### → Modern trumpets

- Vincent Bach
- Yamaha
  - Yamaha custom

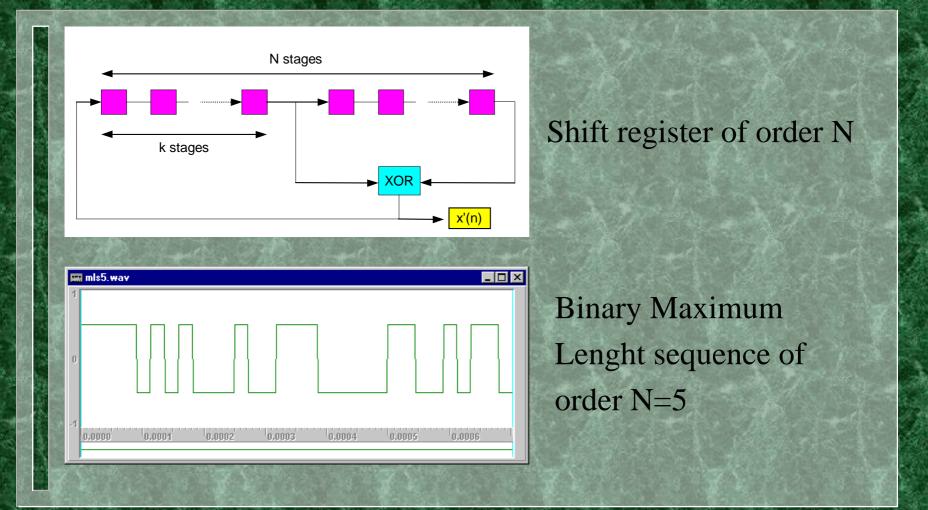
### →Baroque age trumpets

- Natural
- Hunting

# Virtual trumpet reconstruction

- The impulse response (mouthpiece -> radiated field) characterizing different instruments are measured
- A music piece is played on one instrument, and recorded in anechoic environment
- The impulse response of this instrument is inverted
- The anechoic recording is deconvolved by convolution with the inverse filter
- The deconvolved recording is used as the starting point for subsequent reconvolutions with the IRs of the different instruments

# Measurement method #1: MLS

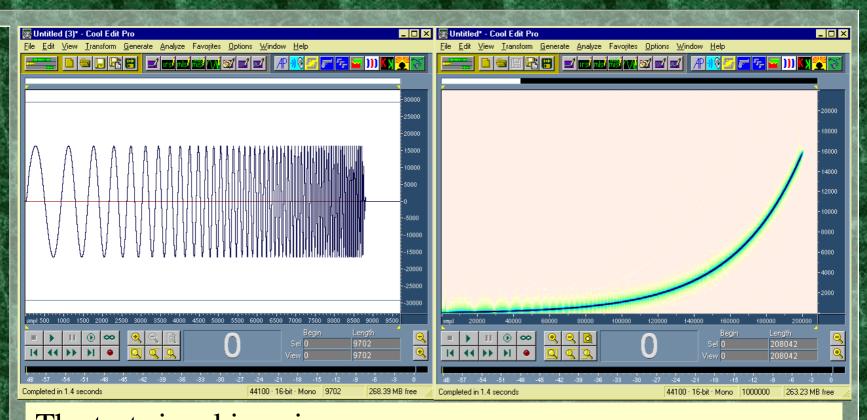


## MLS Method: Impulse Response deconvolution

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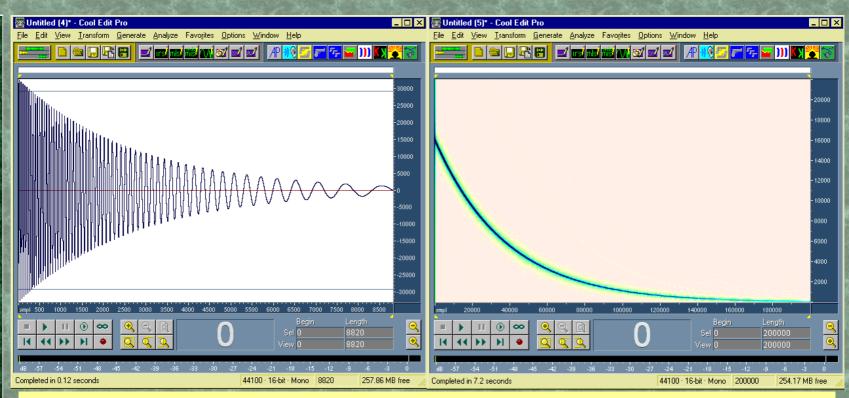
CoolEditPro is employed for simultaneous playback and recording – thereafter, a special plug-in is invoked for deconvolving the impulse response

### Measurements method #2: exponential sweep



The test signal is a sine sweep: the frequency exponentially increases with time

## Sweep method: impulse response deconvolution



The impulse response is recovered by convolving the system's response with a proper inverse filter, obtained by the time-reversal mirror of the excitation signal, with a 6dB/octave equalization

### Measurements on first trumpet



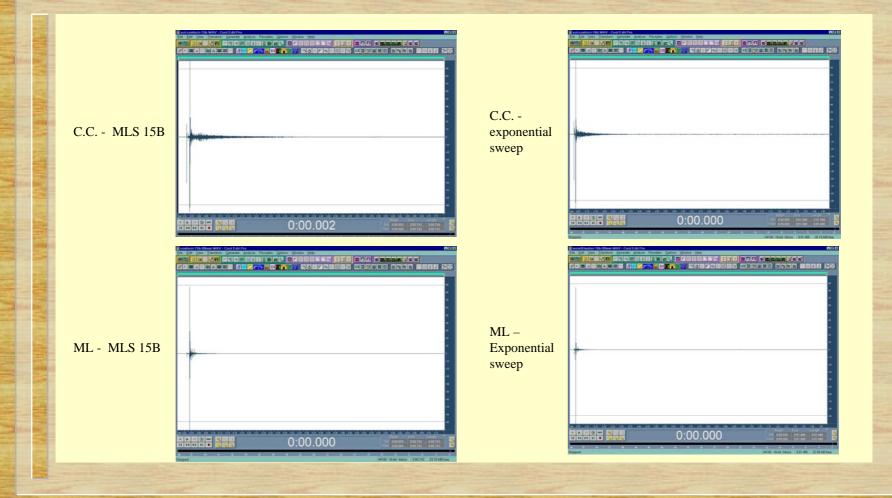
### **Conforzi-Callegari natural trumpet** (a tonal copy of the "Wilhelm Magnus Ehe I" model, XVII century)

### Measurements on second trumpet



#### **Hunting-trumpet Meinl&Lauber**

# Results of the measurements



### Computation of inverse filters with the Kirkeby (Farina) method

The original response h(t) is first FFT transformed:

$$C(\omega) = FFT[h(t)]$$
<sup>(1)</sup>

Then the complex spectrum C is inverted:

$$C_{inv}(\omega) = \frac{Conj[C(\omega)]}{Conj[C(\omega)] \cdot C(\omega) + \varepsilon(\omega)}$$
<sup>(2)</sup>

And the result is back-transformed to time domain

$$h_{inv}(t) = IFFT[C_{inv}(\omega)]$$
 (3)

## The measurements of IR and FIR

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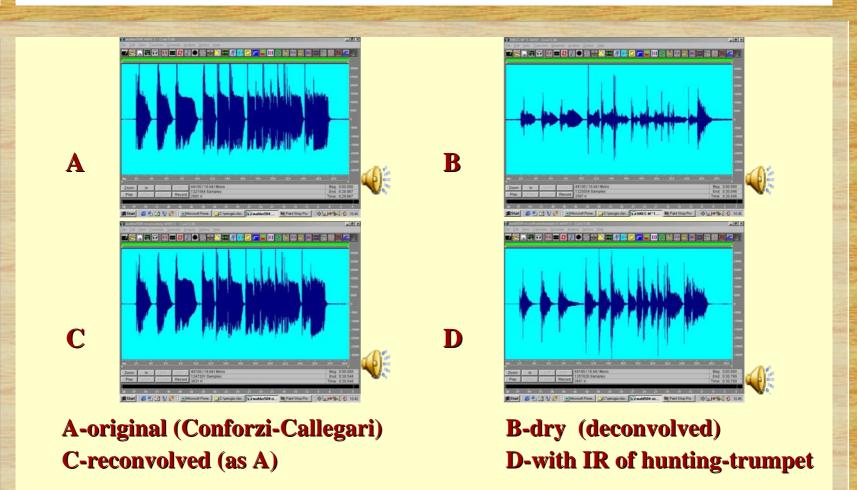
#### **IR measurements:**

- Maximum length sequence
- Exponential sine sweep

#### **Inverse Filter calculation:**

- Toeplitz technique (Morjoupolous 1985)
- <u>Kirkeby technique</u> (Kirkeby, Farina 1998)

### The reconstruction of sound



# Conclusions and remarks:



- → The measurement of IR is feasible in trumpets – the sweep method is better than MLS
- → The computation of inverse filter is better with Kirkeby-Farina method
- The measurements could be improved with smaller microphones (1/4")

# Future developments

- As the new sweep measurement method also characterizes the not-linear response of the instrument, a multiple order convolution will be employed for attempting the virtual recreation of the harmonic distortion.
- The reciprocity method will be attempted (as already done on violins)
- A subjective listening experiment will be started, for trying to understand the connection between measurable objective parameters and the perceived musical quality

## Internet references

CIARM site on musical acoustics: <u>HTTP://www.ciarm.ing.unibo.it</u>

Aurora site (software plug-ins for measurements and convolution):

<u>HTTP://www.ramsete.com/aurora</u> (info) FTP://pcangelo.ramsete.com/aurora (download)