Investigation of Listening Conditions for Multichannel Sound Systems

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- Subjective and objective description
- New parameters
- Subjective tests, results, comparison
- Modeling
- Conclusions

Introduction

- Multichannel audio…
  - testing different formats - listening tests
- Listening conditions...
  - acoustical properties of sound field
  - “small” rooms in the acoustic sense
- Recommendations...
  - more research, new parameters are needed
- Prediction and design using models (CAE)

Subjective Quality - Objective Aspects

- Description of acoustical features in a room

  set of subjective parameters…

  … corresponding objective parameters

- Finding new objective parameters

  … from room impulse responses

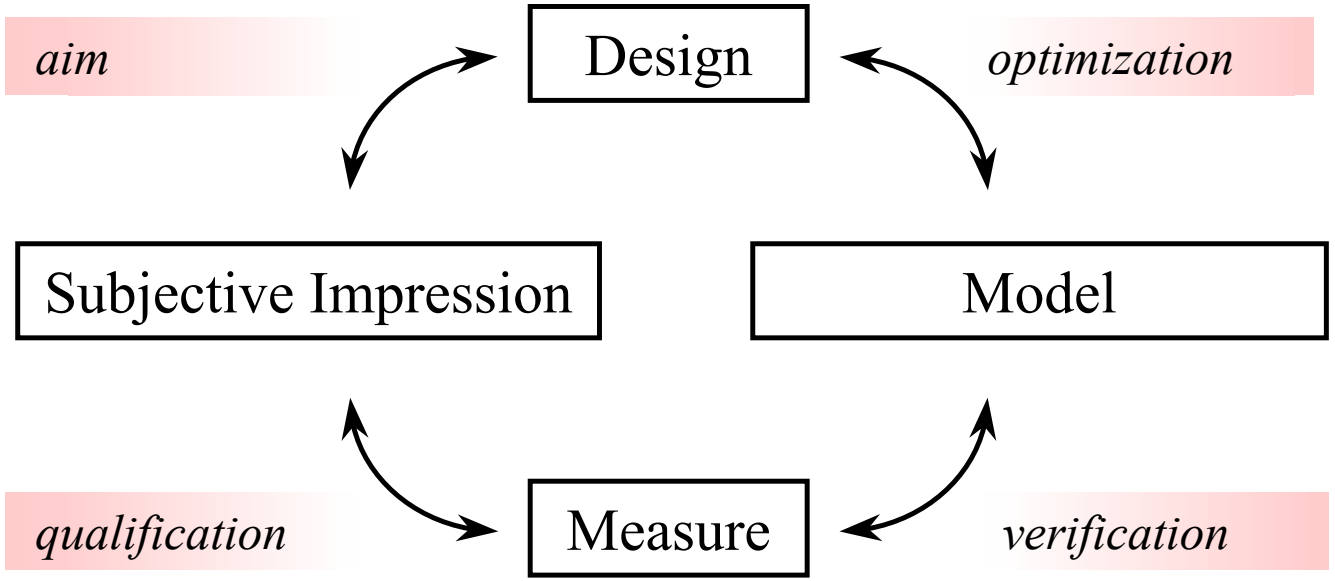
  … from binaural impulse responses

- Investigation of room-speaker interaction

  multichannel systems → same method

  two-channel systems → same method

New parameters - Considerations



… what is a simple connection?

Energy Decay Curves (EDC)

- Calculation

$$EDC(t) = 1 - \frac{\int_0^t p^2(t)dt}{\int_0^\infty p^2(t)dt}$$

… shows the temporal distribution of received energy

- Reasons for choosing EDCs
  - most of the parameters are in direct connection
  - easy to measure
  - relatively easy to model and compare

Proposed Parameters

- Energy ratios…

$$k_1(t) = 10 \cdot \log_{10} \frac{E_{0-t}}{E_{0-\infty}} [dB] \quad \text{or} \quad k_2(t) = 10 \cdot \log_{10} \frac{E_{0-t}}{E_{t-\infty}} [dB]$$

$$t = 5 \ldots 80ms$$

- Modified M-factor

$$M = k_2(20ms) - k_2(5ms)\,[dB]$$

- Center time

$$t_S = \frac{\int_0^\infty t \cdot p^2(t)dt}{\int_0^\infty p^2(t)dt} [s]$$

Subjective Tests

- To find the relationship...
- First part
  - 6 two-channel stereo listening/control rooms
  - 40 minutes long demo records
  - 10 experts
- Second part
  - 2 multichannel listening rooms
  - 30 minutes long demo records
  - 6 experts

Questionnaire for two-channel

Listening Test - Two-channel

Name:	Room:	*Magyar Rádi*
Date:	Test material:	*RT*
Number of listening position:		

Value must lie within 1 and 6: 1 means the worst, 6 means the best verdict.

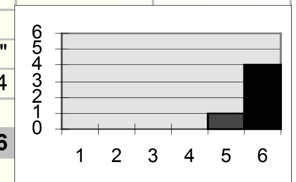
	FEATURE	MARK	REMARK
1.	Stereo accuracy		
2.	Spatial impression		
3.	Transparency		
4.	Timbre		
5.	Frequency response		
6.	Room resonance		
7.	Position dependence		
8.	Other resonance (e.g. equipment)		
9.	Noise from equipment and outside		
10.	Main impression		
11.	Comfort		

THE AES 16th international Conference on Spatial Sound Reproduction

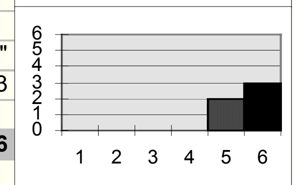
Processing the results - "good"

Control Room No. 22

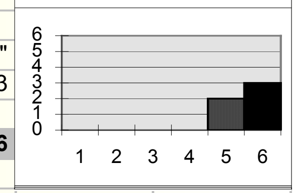
1 Stereo accuracy					
"1"	"2"	"3"	"4"	"5"	"6"
0	0	0	0	1	4
				median:	**6**



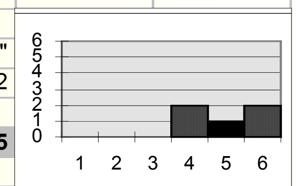
2 Spatial impression					
"1"	"2"	"3"	"4"	"5"	"6"
0	0	0	0	2	3
				median:	**6**



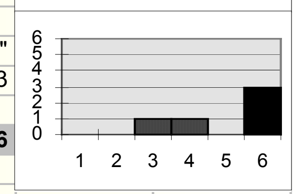
3 Transparency					
"1"	"2"	"3"	"4"	"5"	"6"
0	0	0	0	2	3
				median:	**6**



10 Main impression					
"1"	"2"	"3"	"4"	"5"	"6"
0	0	0	2	1	2
				median:	**5**



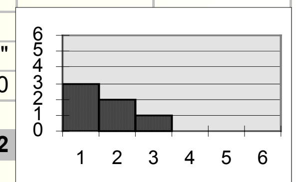
11 Comfort					
"1"	"2"	"3"	"4"	"5"	"6"
0	0	1	1	0	3
				median:	**6**



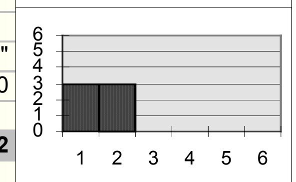
Processing the results - “poor”

Listening room of the Musical Director

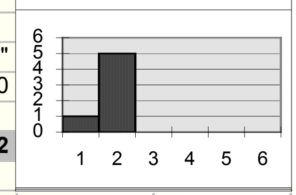
1 Stereo accuracy					
"1"	"2"	"3"	"4"	"5"	"6"
3	2	1	0	0	0
				median:	2



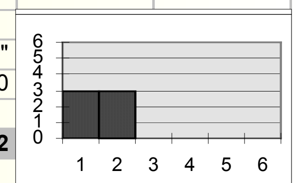
2 Spatial impression					
"1"	"2"	"3"	"4"	"5"	"6"
3	3	0	0	0	0
				median:	2



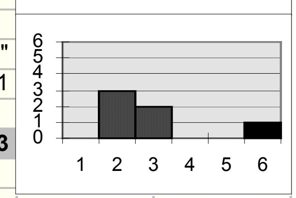
3 Transparency					
"1"	"2"	"3"	"4"	"5"	"6"
1	5	0	0	0	0
				median:	2



10 Main impression					
"1"	"2"	"3"	"4"	"5"	"6"
3	3	0	0	0	0
				median:	2



11 Comfort					
"1"	"2"	"3"	"4"	"5"	"6"
0	3	2	0	0	1
				median:	3



Questionnaire for multichannel

Listening Test - Multichannel

Name:	Room:	*Magyar Rádi*
Date:	Test material:	*RT*
Number of listening position:		

Value must lie within 1 and 6: 1 means the worst, 6 means the best verdict.

	FEATURE	MARK	REMARK
1.	Stereo accuracy from front		
2.	Sense of presence		
3.	Spatial impression		
4.	Stereo accuracy from behind		
5.	Transparency		
6.	Timbre		
7.	Frequency response		
8.	Room resonance		
9.	Position dependence		
10.	Other resonance (e.g. equipment)		
11.	Noise from equipment and outside		
12.	Main impression		
13.	Comfort		

Measurements using MLSSA

- Two-channel stereo listening/control rooms

	St1	St6	St8	St22	St23	St24
k_1 L (dB)	-0.23	-0.80	-0.47	-0.29	-0.26	-0.11
k_1 R (dB)	-0.25	-0.61	-0.56	-0.31	-0.28	-0.14
k_2 L (dB)	12.60	6.94	9.39	11.63	12.09	15.70
k_2 R (dB)	12.20	8.24	8.58	11.25	11.75	14.77
t_S L (ms)	10.46	18.93	17.32	12.09	10.59	4.14
t_S R (ms)	10.53	16.69	20.90	12.98	11.40	5.73

Measurements using MLSSA - continued

- Multichannel listening rooms

	FL	FC	FR	SL	SR
k_1 (dB)	-0.11	-0.17	-0.14	-0.15	-0.08
k_2 (dB)	15.70	13.96	14.77	14.54	17.13
t_S (ms)	4.14	5.43	5.73	7.11	4.30
M (dB)	3.33	2.60	3.30	3.26	2.86

	FL	FLSW	FC	FCSW	FR	FRSW	SL	SR
k_1 (dB)	-0.14	-0.15	-0.13	-0.13	-0.14	-0.13	-0.17	-0.15
k_2 (dB)	14.69	14.62	15.13	15.17	14.67	15.13	13.9	14.49
t_S (ms)	5.77	7.41	5.58	6.30	5.72	4.90	6.44	5.86
M (dB)	3.33	3.78	3.56	3.28	2.78	2.83	2.90	3.46

Results - comparison

Calculated correlation coefficients

	k_1	k_2	t_S	M
spatial impression	0.74	0.74	0.78	0.69
timbre	0.43	0.43	0.75	0.81
transparency	0.45	0.45	0.88	0.75
stereo accuracy	0.79	0.79	0.71	0.68

Conclusions

- t_S ~ transparency and spatial impression
- M-factor ~ timbre
- k_1 and k_2 ~ stereo accuracy

Modeling

- Aim of modeling…

  … prediction of the selected parameters

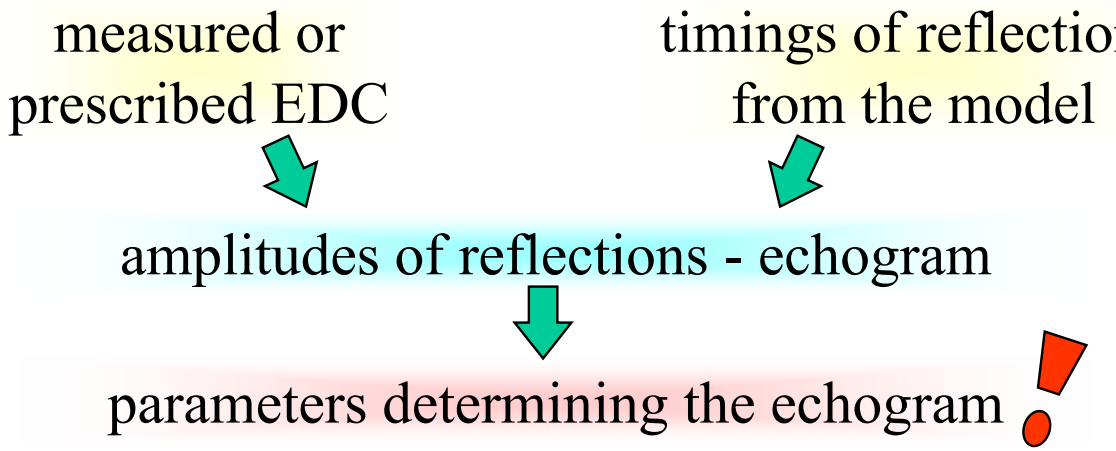
- Modeling method: beam-tracing

- Verification - predicted and measured data
  - global parameters (e.g. RT) agreed well
  - local parameters showed discrepancies

- Sources of errors
  - errors of modeling parameters (e.g. absorption coefficients)
  - errors of the modeling method (non-specular phenomena)

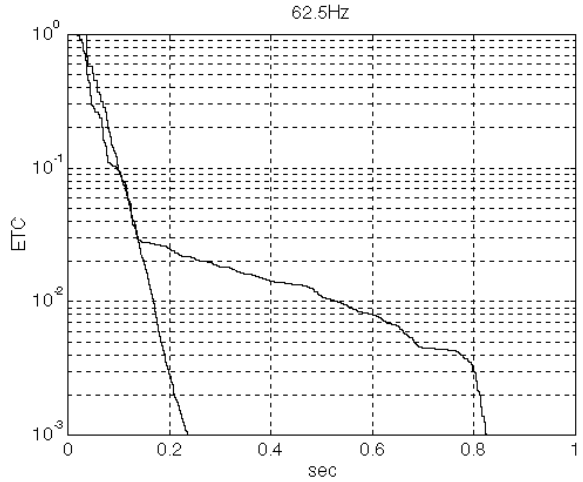
EDC fitting - an inverse method

- Basic assumption…
  - parameter errors are greater than the errors of the modeling method
  - temporal distribution of received energy (EDC) can be predicted accurately enough
- Theory…



Application of the inverse method

- Checking the modeling parameters…



… from the measured EDC

e.g. calculation of absorption coefficients

- Straightforward design for given criteria

… from objective parameters

… create an ideal EDC

… get the needed modeling parameters !

Conclusions

- New objective parameters
  to describe the subjective impression
- Subjective tests showed correlations
- Modeling can be optimized
- Proposed common criteria: EDC

- More subjective tests are needed…
- Binaural parameters?
- Verification of inverse methods is needed...