

Contents

Abstract	xix
Überblick	xxi
Acknowledgements	xxiii
Conventions	xxv
1 Introduction	1
1.1 Malleability of Time	2
1.2 Scope and Context of this Thesis	3
1.3 Contributions	5
1.4 Structure	6
2 Time Design	9
2.1 A Time-Design Space	10
2.1.1 Conceptual vs. Physical Interaction	11
2.1.2 Multiple Time Domains	15
2.2 User: Conducting Gesture Recognition	16
2.2.1 Design	18
2.2.2 Feature Detectors	20
Wiggle Profile	21

Up-Down Profile	21
Four-Beat Neutral-Legato Profile	22
2.2.3 Profile Selection	24
2.2.4 Discussion	25
2.3 User: Rhythmic Analysis of Human Motion	25
Terminology	26
2.3.1 Design	26
Movement Detection	27
Interval Analysis	27
Frequency Analysis	29
Data Fusion	30
Impulse Folding	31
Impulse Clustering	31
2.3.2 Discussion	31
2.4 Medium: MPEG-7	33
2.5 Medium: Automatic Beat Detection	34
2.6 Technology: Video Frame Interpolation	37
2.7 Technology: Audio Time-Stretching	40
2.7.1 Basic Phase Vocoder	42
2.7.2 Scaled Phase-Locked Phase Vocoder	44
2.7.3 The PhaVoRiT Algorithm	45
Multiresolution Peak-Picking (MRPP)	46
Sinusoidal Trajectory Heuristics (STH)	47
Silent Passage Phase Reset (SPPR)	47
2.7.4 Discussion	48

2.8	Closing Remarks	49
3	The Problem of Mappings	51
3.1	Beat Timing in Conducting Gestures	52
	Related Work	53
3.1.1	Experiment Scope and Objectives	54
3.1.2	Hypotheses	55
3.1.3	Experiment Setup	57
	Participants	58
	Procedure	58
3.1.4	Results	59
	Conductors vs. Non-conductors	59
	Effect of Conducting Experience	60
	Effect of Musical Instrument Experience	61
	Effect of a Metaphor on Conducting	64
	Summary of Results	65
3.1.5	Discussion	65
3.1.6	Design Implications	68
3.2	Rhythmic Correction	68
3.2.1	Concept	69
3.2.2	Experiment	70
3.2.3	Results	72
3.3	Latency in Audio Time-Stretching	73
3.3.1	Interpreting Time-Stretched Audio	76
	Black-Box Approach	77
	Hop-Factor Approach	77

Overlap-Add Approach	78
Other Considerations	80
3.3.2 Startup Latency	81
3.3.3 Dynamic Latency	83
3.3.4 Discussion	85
3.4 Synchronization	85
3.4.1 A Closed Loop System	86
3.4.2 Responding to Timebase Changes	88
3.4.3 Discussion	90
3.5 Closing Remarks	92
4 Semantic Time	95
A Conceptual Model Problem	96
4.1 Related Work	96
4.2 Time as a Hierarchy	99
4.3 Synchronization as Constraints	101
4.4 An Algebra for Time	102
4.4.1 Rhythm Maps	103
4.4.2 Concatenation	104
4.4.3 Scaling	105
4.4.4 Averaging	107
4.4.5 Algebraic Properties	108
4.5 Closing Remarks	111
5 The Semantic Time Framework	113
5.1 Design Principles	117

5.2	Semantic Time Framework Version 1 (STFv1)	119
5.2.1	Design	119
	Timebases	120
	Streams	120
	Effects	120
	Graphs	122
5.2.2	Implementation	124
5.2.3	Discussion	124
5.3	Semantic Time Framework Version 2 (STFv2)	126
5.3.1	Design	127
	Time Maps	128
	Nodes	128
	Pipelines	128
	Synchronizers	129
5.3.2	Implementation	130
5.3.3	Discussion	131
5.3.4	Example: <i>HelloSTF</i>	132
5.3.5	Example: <i>MetroSync</i>	135
5.3.6	Comparison With Other Frameworks	137
5.4	Closing Remarks	138
6	Sample Systems	141
6.1	Personal Orchestra	142
6.1.1	Personal Orchestra 1 (<i>The Virtual Conductor</i>)	144
6.1.2	Personal Orchestra 2 (<i>You're the Conductor</i>)	147
6.1.3	Personal Orchestra 3 (<i>Maestro!</i>)	148

6.1.4	POLite	152
6.1.5	Discussion and Future Directions	155
6.2	DiMaß	155
6.2.1	Design	159
6.2.2	An Improved Synchronization Algorithm	161
6.2.3	Forwards and Backwards Scrubbing	164
6.2.4	Beat Tapper	164
6.2.5	Discussion and Future Directions	166
6.3	iRhyMe	167
6.3.1	Quartz Composer	168
6.3.2	Implementation	169
6.3.3	Discussion	170
6.4	Closing Remarks	170
7	Future Work	173
7.1	Time-Design Space	173
7.2	Semantic Time	174
7.3	Semantic Time Framework	175
7.4	Design Patterns	176
7.5	Semantic Time Applications	176
8	Conclusions	179
A	Sampling and Quantization Overview	183
A.1	Sampling	183
A.2	Quantization	184
A.3	Resampling	185

A.4 Closing Remarks	192
B Fourier Theory Overview	193
B.1 The Fourier Transform	193
B.2 Windowing	194
B.3 The Short-Time Fourier Transform	195
B.4 Closing Remarks	196
C Source Code Listings	197
C.1 HelloSTF	197
C.1.1 HelloSTFController.h	197
C.1.2 HelloSTFController.m	199
C.2 MetroSync	202
C.2.1 MetronomeView.h	202
C.2.2 MetronomeView.m	204
Bibliography	209
Index	227
Curriculum Vitae	231