

CONTENTS

1	Introduction	1
1.1	European Extremely Large Telescope	3
1.2	The MICADO instrument	8
1.3	Disturbance mitigation in MICADO	11
1.4	State of the art	19
1.5	Aim of the work and outline	24
2	Modeling and control of the derotator	25
2.1	Modeling	27
2.1.1	Mechanics	28
2.1.2	Elasto-plastic friction model	32
2.2	Friction compensation scheme	34
2.3	Laboratory results	37
2.3.1	Model identification	37
2.3.2	Model-based disturbance compensation	42
2.4	Conclusion	43
3	Modeling of the adaptive optics	45
3.1	Telescope optics	46
3.1.1	Mirror kinematics	48
3.1.2	Image motion	50
3.1.3	Detector image	51
3.2	Atmospheric turbulence	53
3.2.1	Kolmogorov's turbulence description	53
3.2.2	Light propagation through the atmosphere	55
3.2.3	Temporal behavior of the atmosphere	57
3.3	Structural vibrations	60
3.4	Sensors	61
3.4.1	Pyramid wavefront sensor	61
3.4.2	Accelerometers	65
3.5	Compensation mirrors	68
3.5.1	Deformable mirror	68
3.5.2	Tip-tilt mirror	78
3.6	Wavefront control	87
3.7	Performance evaluation	88
3.8	Conclusion	89

4	Disturbance compensation schemes	91
4.1	Integral action	92
4.1.1	Dual stage control	92
4.1.2	Linear quadratic integral control	94
4.1.3	Model predictive control	96
4.2	Disturbance observer	99
4.3	Disturbance feedforward control	102
4.4	Multi-rate disturbance observer	105
4.5	Simulation results	107
4.5.1	Integral action	107
4.5.2	Disturbance observer	112
4.5.3	Disturbance feedforward control	116
4.5.4	Multi-rate disturbance observer	118
4.6	Laboratory results	120
4.6.1	Frequency behavior	122
4.6.2	Telescope benchmark signals	123
4.6.3	Disturbance feedforward control	124
4.7	Conclusion	125
5	Tip-tilt disturbance feedforward control at the LBT	127
5.1	Large Binocular Telescope	127
5.1.1	Adaptive Optics	128
5.1.2	Optical path difference and Vibration Monitoring System	129
5.2	Implementation	131
5.2.1	Coordinate transformation for the ASM	132
5.3	Tip-Tilt sensing verification	134
5.4	Simulation study	137
5.5	Daytime tests	139
5.6	Conclusion	143
6	Conclusion	145
Appendix		
A	Fundamentals of optics	149
B	Friction modeling	153
Acronyms		158
Symbols		159
List of Figures		167
List of Tables		171
Bibliography		173