

Contents

Abbreviations	xi
Mathematical notation	xiii
1 Introduction	1
2 Assessment of coregistration uncertainties	7
2.1 Introduction to the problem	7
2.2 Instrumentation	10
2.3 Head coordinate system	11
2.4 Rotation by quaternions	11
2.5 Coregistration model	12
2.5.1 MEG-to-Head	12
2.5.2 Head-to-MRI	14
2.6 Data sets	16
2.6.1 MEG-to-Head	16
2.6.2 Head-to-MRI	16
2.7 Scales of the coordinate systems	16
2.8 Coil localization errors	18
2.9 Estimating errors from residuals	19
2.9.1 General considerations	19
2.9.2 Inference of errors by simulation	23
2.10 Coregistration parameter sampling	25
2.11 MEG-to-MRI	27
3 Uncertainty and sensitivity analysis	29
3.1 Introduction	29
3.2 Stochastic spectral methods	30
3.2.1 Representation of random processes on polynomial basis . . .	30
3.2.2 Smolyak pseudospectral approximation method	33

3.2.3	Error estimates of spectral approximations	43
3.2.4	Statistics from polynomial coefficients	44
3.2.5	Variance based sensitivity analysis	44
3.3	Coregistration parameter distribution	47
3.4	Definition of input variables	48
3.4.1	Static coregistration uncertainties	48
3.4.2	Head movements	49
3.4.3	Target registration error	50
3.5	Forward modeling	51
3.5.1	Source space	51
3.5.2	Regions of interest	52
3.5.3	Volume conductor and boundary element method	54
3.5.4	Expansion of forward operators	55
3.5.5	Error of forward computations	56
3.6	MEG source estimation	57
3.6.1	Introduction	57
3.6.2	Beamformer	58
3.6.3	sLORETA	59
3.6.4	Expansion of source estimators	60
3.6.5	Verification	61
3.6.6	Source amplitude maximum distribution	62
4	Results	65
4.1	Errors and residuals	65
4.1.1	MEG-to-Head	65
4.1.2	Head-to-MRI	67
4.2	Parameter-distribution sampling	68
4.2.1	MEG-to-Head and head-to-MRI	68
4.2.2	MEG-to-MRI	69
4.3	Effects of coregistration uncertainties	71
4.3.1	Forward computation	71
4.3.2	Source estimates	75
4.3.3	Error estimates	84
5	Discussion and conclusions	87
5.1	Quality assessment of MEG-to-MRI coregistrations	87
5.1.1	Findings	87
5.1.2	Practical recommendations	91

Contents	ix
5.1.3 Conclusion	92
5.2 Effects of coregistration uncertainty on forward computations	93
5.3 Effects of coregistration uncertainty on source estimates	95
List of Figures	107
List of Tables	115