

Contents

1	Introduction	1
1.1	Motivation	1
1.2	Objectives	5
1.3	Main contributions	7
1.4	Thesis framework	9
1.5	Outline	10
2	The human liver	13
2.1	Liver anatomy	13
2.2	Liver cancer	16
2.3	Cancer diagnosis	18
2.4	Cancer treatment	19
2.5	Compensation of the patient's breathing	23
2.6	Conclusions	24
3	Background literature	27
3.1	Introduction	27
3.2	<i>Ex vivo</i> biomechanical modeling of the liver	30
3.3	<i>In vivo</i> biomechanical modeling of the liver	39

3.4	Conclusions	46
4	Methodology	49
4.1	Soft tissue biomechanics	50
4.1.1	Biomechanical models	51
4.1.2	Finite element method	57
4.2	Similarity coefficients for volume comparison	58
4.2.1	Similarity coefficients based on overlap	60
4.2.2	Similarity coefficients based on distances	63
4.2.3	Geometric Similarity Function	64
4.3	Parameter optimization	66
4.3.1	Local optimization	67
4.3.2	Global optimization	69
4.4	Conclusions	77
5	Analysis of the biomechanical behavior of <i>ex vivo</i> lamb livers	79
5.1	Introduction	80
5.2	Materials and methods	80
5.2.1	Identification of the elastic constants	81
5.2.2	Validation of the biomechanical models	83
5.3	Results	88
5.3.1	Results of the identification of the elastic constants	88
5.3.2	Results of the validation	93
5.4	Discussion	94
5.5	Conclusions	96
6	Non-invasive estimation of the elastic constants of liver biomechanical models	99
6.1	Introduction	100
6.2	Materials and methods	101
6.2.1	Experimental setup	102
6.2.2	One-parameter optimization	105

6.2.3	Two-parameter optimization	107
6.3	Results	118
6.3.1	Results of the one-parameter optimization	118
6.3.2	Results of the two-parameter optimization	120
6.3.3	Comparison of the results obtained by the three algorithms	127
6.4	Discussion	129
6.5	Conclusions	131
7	Simulation of the biomechanical behavior of the human liver	133
7.1	Introduction	134
7.2	Materials and methods	136
7.2.1	Proof of concept	141
7.2.2	Elastic constants for the real case	143
7.3	Results	144
7.3.1	Results from the proof of concept	144
7.3.2	Results for the real case	146
7.4	Discussion	149
7.5	Conclusions	151
8	Conclusions and future prospects	153
8.1	General conclusions	153
8.2	Final conclusions	155
8.3	Future prospects	156
8.4	Scientific publications from this thesis	157
8.4.1	Journal publications	157
8.4.2	Conference papers	158
Bibliography		169