

UNIVERSITY OF LILLE 1  
DOCTORAL SCHOOL OF ENGINEERING  
SCIENCE

# P H D T H E S I S

to obtain the title of

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**Specialty: COMPUTER SCIENCE**

Defended by

Olivier COMAS

## Real-time Soft Tissue Modelling on GPU for Medical Simulation

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# Contents

<b>Contents</b>	<b>i</b>
<b>I Introduction</b>	<b>1</b>
<b>1 Medical simulation</b>	<b>3</b>
1.1 General context and goal: medical training, patient-specific planning and per-operative guidance . . . . .	3
1.2 Challenges (trade-off between accuracy and real-time) . . . . .	3
<b>2 One key point in medical simulation: soft-tissue modelling</b>	<b>5</b>
2.1 Necessary background in continuum mechanics . . . . .	5
2.1.1 Deformation tensor and strain tensor . . . . .	5
2.1.2 Stress and constitutive laws . . . . .	5
2.2 Tissue characterisation . . . . .	5
2.2.1 Material models for organs (non-linear, visco-elastic and anisotropic) . . . . .	5
2.2.2 Measure/estimation of model parameters . . . . .	5
<b>3 Main principles of Finite Element Method (or how to solve equations of continuum mechanics from previous section)</b>	<b>7</b>
3.1 Discretisation . . . . .	7
3.2 Derivation of element equations . . . . .	7
3.3 Assembly of element equations . . . . .	7
3.4 Solution of global problem . . . . .	7
<b>II Solid organs modelling</b>	<b>9</b>
<b>4 State of art: FEM</b>	<b>11</b>
<b>5 Linear not accurate =&gt; Non-linear FEM =&gt; Introduction of TLED</b>	<b>13</b>
5.1 Differences with classic FEM and reasons of its efficiency . . . . .	13
5.2 Visco-elasticity and anisotropy added ( <a href="#">MICCAI 2008</a> ; <a href="#">MedIA 2009</a> ) .	13
<b>6 GPU implementation of TLED</b>	<b>15</b>
6.1 What is GPGPU . . . . .	15
6.2 Re-formulation of the algorithm for its Cg implementation . . . . .	15
6.3 CUDA implementation/optimisations ( <a href="#">ISBMS 2008a</a> ) . . . . .	15

<b>7 Implementation in SOFA</b>	<b>17</b>
7.1 Presentation of SOFA project and architecture . . . . .	17
7.2 Implementation in SOFA and TLED released in open-source . . . . .	17
 <b>III Hollow organs modelling</b>	 <b>19</b>
<b>8 State of art: hollow structures</b>	<b>21</b>
8.1 Non-physic approaches (computer graphics stuff) . . . . .	21
8.2 Physically accurate approches (plates/shells) . . . . .	21
<b>9 Colonoscopy simulator project</b>	<b>23</b>
9.1 Project introduction . . . . .	23
9.2 Mass-spring model for colon implemented on GPU ( <a href="#">ISBMS 2008b</a> ) .	23
<b>10 More accurate: a co-rotational triangular shell model (<a href="#">ISBMS 2010</a>)</b>	<b>25</b>
10.1 Model description . . . . .	25
10.2 Validation . . . . .	25
10.3 Application to implant deployment simulation in cataract surgery . .	25
<b>11 'Shell meshing' technique (<a href="#">MICCAI 2010</a>)</b>	<b>27</b>
11.1 State of art: reconstruction/simplification . . . . .	27
11.2 Our method . . . . .	27
<b>12 Applications to medical simulation</b>	<b>29</b>
12.1 Nice medical stuff to show . . . . .	29
12.2 Interaction solid/hollow organs . . . . .	29
 <b>IV Conclusion</b>	 <b>31</b>
<b>References</b>	<b>33</b>

# Part I

## Introduction

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# Medical simulation

- 1.1 General context and goal: medical training, patient-specific planning and per-operative guidance
- 1.2 Challenges (trade-off between accuracy and real-time)





# One key point in medical simulation: soft-tissue modelling

## 2.1 Necessary background in continuum mechanics

### 2.1.1 Deformation tensor and strain tensor

### 2.1.2 Stress and constitutive laws

## 2.2 Tissue characterisation

### 2.2.1 Material models for organs (non-linear, visco-elastic and anisotropic)

### 2.2.2 Measure/estimation of model parameters



# Main principles of Finite Element Method (or how to solve equations of continuum mechanics from previous section)

- 3.1 Discretisation
- 3.2 Derivation of element equations
- 3.3 Assembly of element equations
- 3.4 Solution of global problem



## Part II

# Solid organs modelling

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## CHAPTER 4

# State of art: FEM

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# Linear not accurate $\Rightarrow$ Non-linear FEM $\Rightarrow$ Introduction of TLED

- 5.1 Differences with classic FEM and reasons of its efficiency
- 5.2 Visco-elasticity and anisotropy added ([MICCAI 2008](#); [MedIA 2009](#))



# GPU implementation of TLED

- 6.1 What is GPGPU
- 6.2 Re-formulation of the algorithm for its Cg implementation
- 6.3 CUDA implementation/optimisations ([ISBMS 2008a](#))



# Implementation in SOFA

- 7.1 Presentation of SOFA project and architecture
- 7.2 Implementation in SOFA and TLED released in open-source



## Part III

# Hollow organs modelling





# State of art: hollow structures

- 8.1 Non-physic approaches (computer graphics stuff)
- 8.2 Physically accurate approches (plates/shells)



# Colonoscopy simulator project

## 9.1 Project introduction

## 9.2 Mass-spring model for colon implemented on GPU ([ISBMS 2008b](#))



# More accurate: a co-rotational triangular shell model (ISBMS 2010)

- 10.1 Model description
- 10.2 Validation
- 10.3 Application to implant deployment simulation in  
cataract surgery



# 'Shell meshing' technique (MICCAI 2010)

## 11.1 State of art: reconstruction/simplification

## 11.2 Our method





# Applications to medical simulation

**12.1** Nice medical stuff to show

**12.2** Interaction solid/hollow organs



## Part IV

# Conclusion



# References

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