# Numerical Model of Dynamic Deformation of Fibrous Structural Membranes

Oleksandr HubanovSupervisorprof. habil. dr. Rimantas Kačianauskas

Vilnius Gediminas Technical University

January 4, 2021

## Contents

IN		ODUCTION					
	Prob	olem Formulation					
	Rele	evance of the Thesis					
	The	Γhe Object of Research					
	The	Aim of the Thesis					
	The	The Tasks of the Thesis					
	Rese	earch Methodology					
		ntific Novelty of the Thesis					
		ctical Value of the Research Findings					
	The	Defended Statements					
	App	roval of the Research Findings					
	Stru	acture of the Dissertation					
1	LIT	ERATURE REVIEW					
	1.1	Mitral Valve as Human Body Part					
		1.1.1 Functional Anatomy of Heart and Mitral Valve					
		1.1.2 Mitral Valve Function and Dysfunction					
		1.1.3 Mitral Valve Surgical Repair Techniques					
	1.2	Computational Models					
		1.2.1 Discrete Element Method					
		1.2.2 Fluid-Structure Interaction Models					
	1.3	Modelling of Biological Soft Tissues					
		1.3.1 Soft Fibers Structural Models					
		1.3.2 Mitral Valve and Blood					
		1.3.3 Computational Models for Mitral Valve Repair					
		1.3.4 Conclusions and Thesis Tasks Formulation					
2	Discrete Models of Soft Fibers						
	2.1	Problem Formulation					
	2.2	Basic Equations					
	2.3	Computational Forces					
		2.3.1 Geometrical nonlinearity					
		2.3.2 Nonlinear Elasticity					
		2.3.3 Nonconservative transversial loading					
		2.3.4 Fibers in Fluid					
		2.3.5 Integration Methods					
	2.4	Membrane as A system of Soft Fibers					
3	Application of discrete models						
	3.1	Pulling of Chordae Tendineae					
	3.2	Chordae Tendineae - Membrane Junction					
4	Dev	veloping method of preparing medical data					

	4.1	Patient-Specific Mitral Valve Geometry					
		4.1.1	Echocardiographic Data Acquisition	7			
		4.1.2	Echocardiographic Image Segmentation	7			
	4.2	Patien	t-Specific Geometry Reconstruction	7			
		4.2.1	Simplyfiyng Patient-Specific 3D Model To MassPoints	7			
5	Con	clusion	ns	8			
IN	NTRODUCTION						

#### **INTRODUCTION**

**Problem Formulation** 

Relevance of the Thesis

The Object of Research

The Aim of the Thesis

The Tasks of the Thesis

Research Methodology

Scientific Novelty of the Thesis

Practical Value of the Research Findings

The Defended Statements

Approval of the Research Findings

Structure of the Dissertation

#### LITERATURE REVIEW

- 1.1 Mitral Valve as Human Body Part
- 1.1.1 Functional Anatomy of Heart and Mitral Valve
- 1.1.2 Mitral Valve Function and Dysfunction
- 1.1.3 Mitral Valve Surgical Repair Techniques
- 1.2 Computational Models
- 1.2.1 Discrete Element Method
- 1.2.2 Fluid-Structure Interaction Models
- 1.3 Modelling of Biological Soft Tissues
- 1.3.1 Soft Fibers Structural Models
- 1.3.2 Mitral Valve and Blood
- 1.3.3 Computational Models for Mitral Valve Repair
- 1.3.4 Conclusions and Thesis Tasks Formulation

#### Discrete Models of Soft Fibers

- 2.1 Problem Formulation
- 2.2 Basic Equations
- 2.3 Computational Forces
- 2.3.1 Geometrical nonlinearity
- 2.3.2 Nonlinear Elasticity
- 2.3.3 Nonconservative transversial loading
- 2.3.4 Fibers in Fluid
- ${\bf 2.3.5}\quad {\bf Integration\ Methods}$
- 2.4 Membrane as A system of Soft Fibers

# Application of discrete models

- 3.1 Pulling of Chordae Tendineae
- 3.2 Chordae Tendineae Membrane Junction

# Developing method of preparing medical data

- 4.1 Patient-Specific Mitral Valve Geometry
- 4.1.1 Echocardiographic Data Acquisition
- 4.1.2 Echocardiographic Image Segmentation
- 4.2 Patient-Specific Geometry Reconstruction
- 4.2.1 Simplyfiyng Patient-Specific 3D Model To MassPoints

### Conclusions

# INTRODUCTION