Компьютерная модель распространения звука в легких

А. А. Родионов | 1 к маг.
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Цель работы

Цель работы

- Разработать комп. модель распространения звука в легких.

Цель работы

- Разработать комп. модель распространения звука в легких.
- Изучить поведение звука, эффекты при различных условиях.

Задачи работы

Задачи работы

1. Анализ литературы

Задачи работы

1. Анализ литературы
2. Основывать модель на реальных данных

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1. Анализ литературы
2. Основывать модель на реальных данных
3. Математическая модель

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2. Основывать модель на реальных данных
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4. Компьютерная модель

Задачи работы

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2. Основывать модель на реальных данных
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Анализ литературы

MULTISCALE MODEL. SIMUL. Vol. 13, No. 1, pp. 43–71 © 2015 Society for Industrial and Applied Mathematics

HOMOGENIZATION OF A MODEL FOR THE PROPAGATION OF SOUND IN THE LUNGS*

PAUL CAZEAUX†, CÉLINE GRANDMONT†, AND YVON MADAY‡

Abstract. In this paper, we are interested in the mathematical modeling of the propagation of sound waves in the lung parenchyma, which is a foam-like elastic material containing millions of air-filled alveoli. In this study, the parenchyma is governed by the linearized elasticity equations, and the air by the acoustic wave equations. The geometric arrangement of the alveoli is assumed to be periodic with a small period $\varepsilon > 0$. We consider the time-harmonic regime forced by vibrations induced by volumic forces. We use the two-scale convergence theory to study the asymptotic behavior as ε goes to zero and prove the convergence of the solutions of the coupled fluid-structure problem to the solution of a linear-elasticity boundary value problem.

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Journal of Biomechanics 39 (2006) 2113–2122

JOURNAL OF BIOMECHANICS

www.elsevier.com/locate/jbiomech
www.JBiomech.com

Modeling of weak blast wave propagation in the lung

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Accepted 29 May 2005

4D FEM models of the human thorax

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Abstract: In order to be able to further study 3D EIT lung imaging and to analyse if the movement of the lungs during the breathing cycle can be reconstructed, accurate FEM image in figure 2. This FEM models then are saved using the EIDORS data structure. The models have around 300K elements each.

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Comparison of Poroviscoelastic Models for Sound and Vibration in the Lungs

Noninvasive measurement of mechanical wave motion (sound and vibration) in the lungs may be of diagnostic value, as it can provide information about the mechanical properties of the lungs, which in turn are affected by disease and injury. In this study, two previously derived theoretical models of the vibroacoustic behavior of the lung parenchyma are compared: (1) a Biot theory of poroviscoelasticity and (2) an effective medium theory for compression wave behavior (also known as a "bubble swarm" model). A fractional

Respiratory Medicine (2011) 105, 1396–1403

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Computerized lung sound analysis as diagnostic aid for the detection of abnormal lung sounds: A systematic review and meta-analysis

A comprehensive computational model of sound transmission through the porcine lung

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Ying Peng
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MULTISCALE MODELLING OF SOUND PROPAGATION THROUGH THE LUNG PARENCHYMA*

PAUL CAZEAUX[1,2] AND JAN S. HESTHAVEN[3]

Abstract. In this paper we develop and study numerically a model to describe some aspects of sound propagation in the human lung, considered as a deformable and viscoelastic porous medium (the parenchyma) with millions of alveoli filled with air. Transmission of sound through the lung above 1 kHz is known to be highly frequency-dependent. We pursue the key idea that the viscoelastic parenchyma

Анализ литературы

State of the Art

Respiratory Sounds
Advances Beyond the Stethoscope

HANS PASTERKAMP, STEVE S. KRAMAN, and GEORGE R. WODICK

Department of Pediatrics and Child Health, University of Manitoba, Winnipeg, Manitob
School of Electrical and Computer Engineering, Purdue University, West Lafayette, India

A Numerical Model to study Auscultation Sounds under Pneumothorax conditions

Sridhar Ramakrishnan, *Student Member, IEEE*, Satish Udpa, *Fellow, IEEE*, and Lalita Udpa, *Fellow, IEEE*

PERGAMON
Computerized Medical Imaging and Graphics 26 (2002) 237–246
Computerized Medical Imagin and Graphics
www.elsevier.com/locate/compmedim

A computer model of lung morphology to analyze SPECT images

Jeffry D. Schroeter[a], John S. Fleming[b], Dongming Hwang[c], Ted B. Martonen[d,e,*]

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Received 1 February 2001; accepted 13 January 2002

ISSN 1063-7710, Acoustical Physics, 2013, Vol. 59, No. 6, pp. 709–716. © Pleiades Publishing, Ltd., 2013.
Original Russian Text © A.D. Shiryaev, V.I. Korenbaum, 2013, published in Akusticheskii Zhurnal, 2013, Vol. 59, No. 6, pp. 759–767.

ACOUSTICS OF LIVING SYSTEMS.
BIOLOGICAL ACOUSTICS

Frequency Characteristics of Air-Structural and Structural Sound Transmission in Human Lungs

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Received September 14, 2012

Abstract—From an independent sampling of data on luminal probing of the lungs of 20 people, based on an analysis of the phase characteristics of the coherency function of the signal with linear frequency modulation in a frequency band of 80–1000 Hz recorded above the trachea and different areas of the chest, the frequency selectivity of the structural and air-structural transmission variants has been revealed. It has been established that structural sound transmission on average is observed in a band from 100 to 280 Hz and air-structural propagation lies in the frequency range from 100 to 500–700 Hz. Over areas of the lungs characterized by the presence of aerated tissues (the apex and lower lobe), more frequently there is air-structural transmission, whereas in the vicinity of dense organs of the mediastinum (intercapsular region), on the contrary, structural propagation dominates.

PERGAMON
Computers in Biology and Medicine 31 (2001) 499–511
Computers in Biology and Medicine
www.elsevier.com/locate/compbiomed

Computer simulations of lung airway structures using data-driven surface modeling techniques

Richard M. Spencer[a], Jeffry D. Schroeter[b], Ted B. Martonen[c,d,*]

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[b]*Curriculum in Toxicology, University of North Carolina, Chapel Hill, NC 27599, USA*
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УДК 534.7

МОДЕЛИРОВАНИЕ ПРОЦЕССА РАСПРОСТРАНЕНИЯ ЗВУКА В ГРУДНОЙ КЛЕТКЕ ЧЕЛОВЕКА. ЧАСТЬ 2. АНАЛИЗ АКУСТИЧЕСКИХ СВОЙСТВ В НОРМЕ

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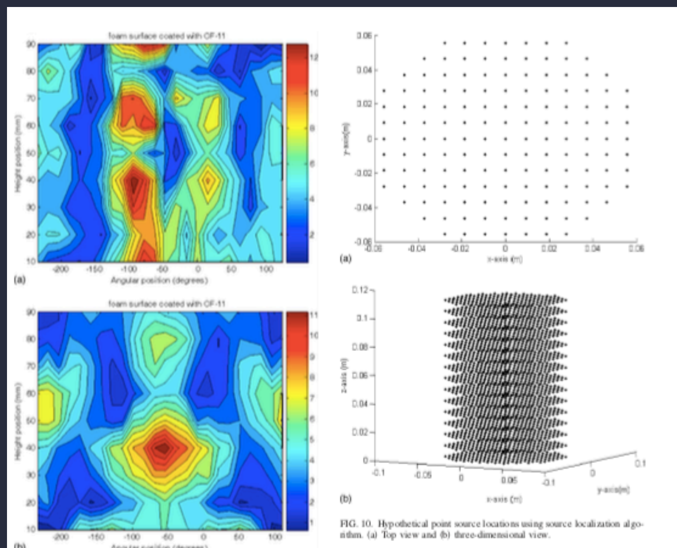
*Институт гидромеханики НАН Украины, Киев
**Киевский национальный университет имени Тараса Шевченко

Анализ литературы



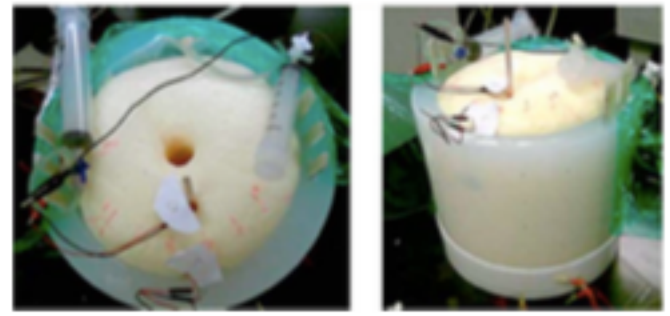


Fig. 6 Photograph of lung and chest wall mechanical phantom. Top and side views. Images show syringes that are used for inputting air into the bladders.

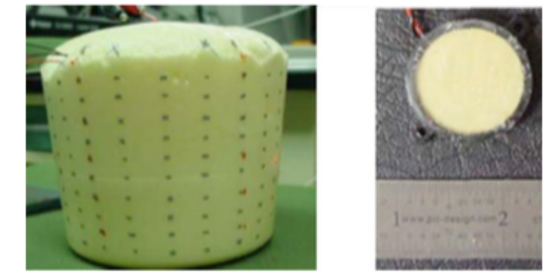


FIG. 5. (Color online) Lung
measurement points and (righ

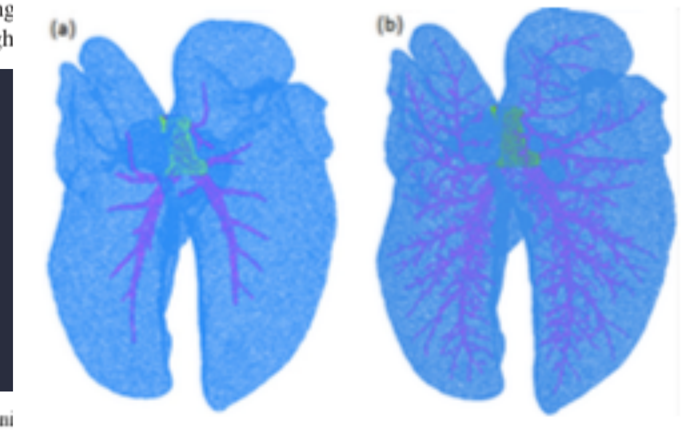


FIG. 5. (Color online) Volume mesh of lung with airway tree: (a) With airway network 1, (b) with airway network 2.

46 P. CAZEAUX, C. GRANDMONT, AND Y. MADAY

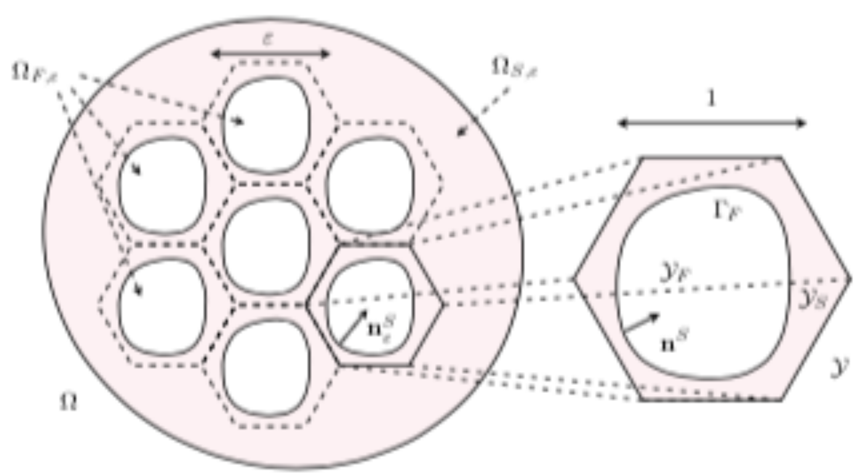
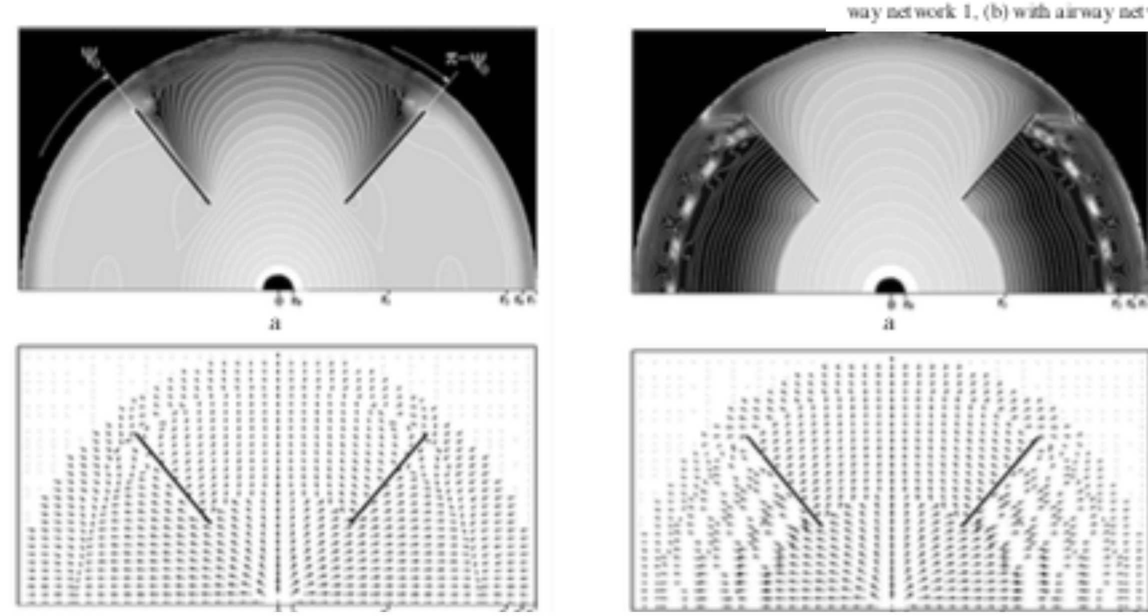


FIGURE 1. *Domain* Ω *and reference cell* $\mathcal{Y}$.

the whole space. The standard example is $\mathcal{Y} = (-1/2, 1/2)^d$ and $\mathbf{Z} = \mathbb{Z}^d$. We can also study, for example, a honeycomb as presented in Figure 1, where $\mathcal{Y}$ is a hexagon with side $a > 0$ such that its volume is 1 and $\mathbf{Z}$ the discrete lattice with basis $(0, \sqrt{3}a)$ and $(3a/2, \sqrt{3}a/2)$ in $\mathbb{R}^2$, or a paving based on the truncated octahedron in $3D$ which is a standard representation of the alveolus [22]. Note that we will always use bold face to denote vectors or spaces of vectors.

ISSN 1028-7507 Акустичний ві



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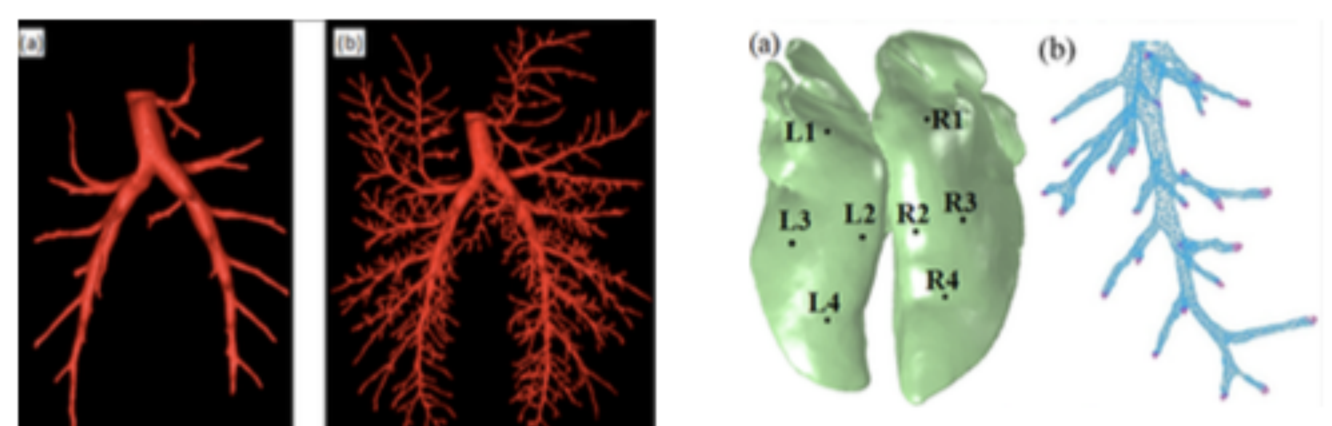
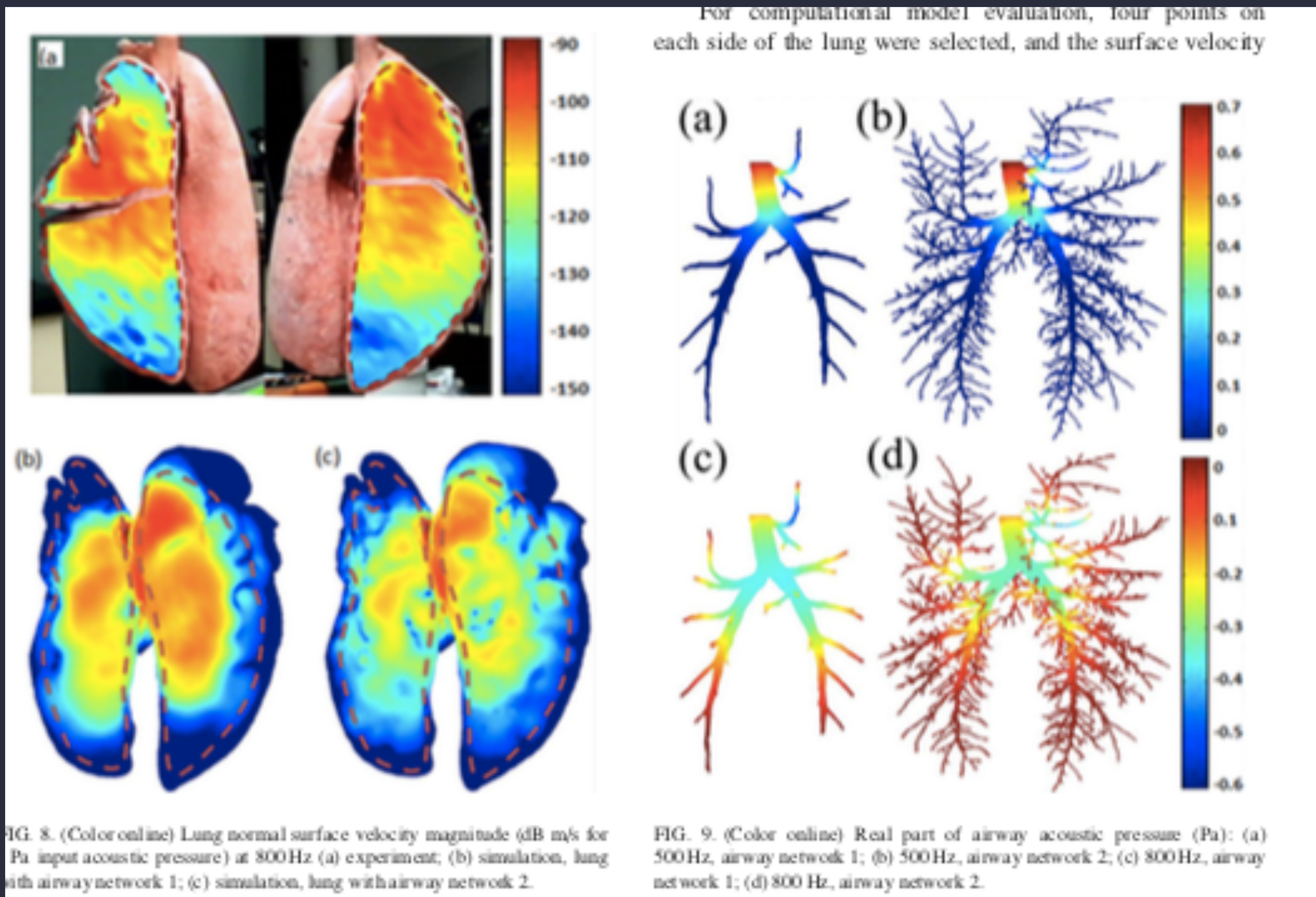
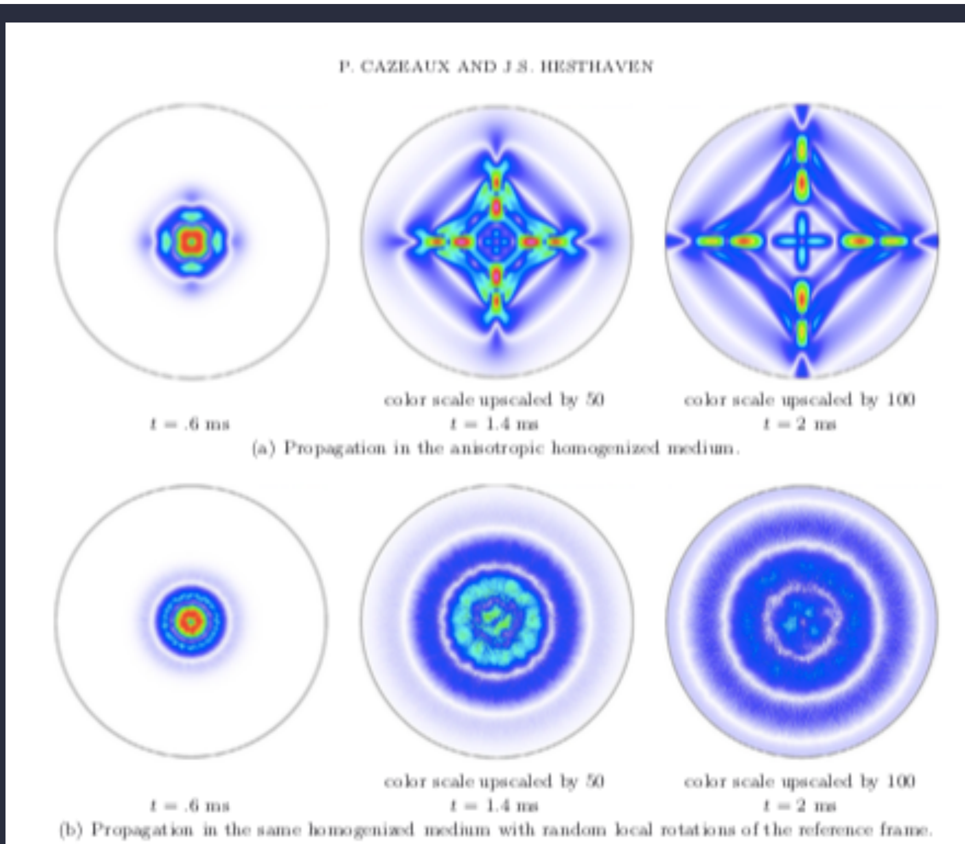
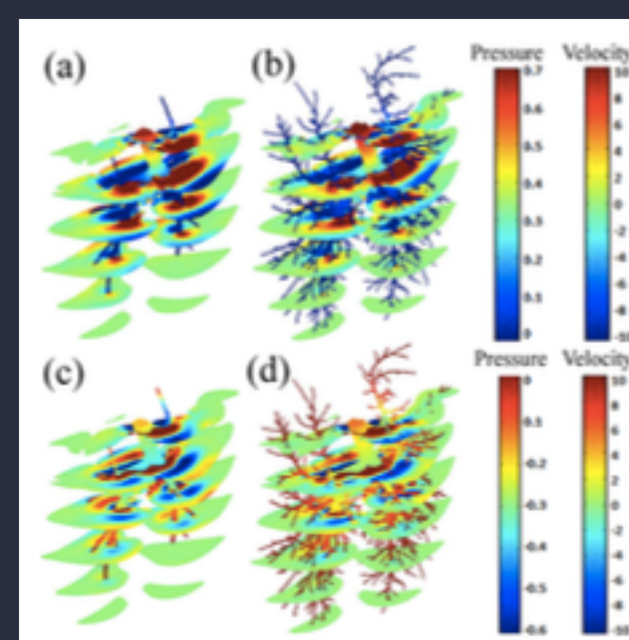


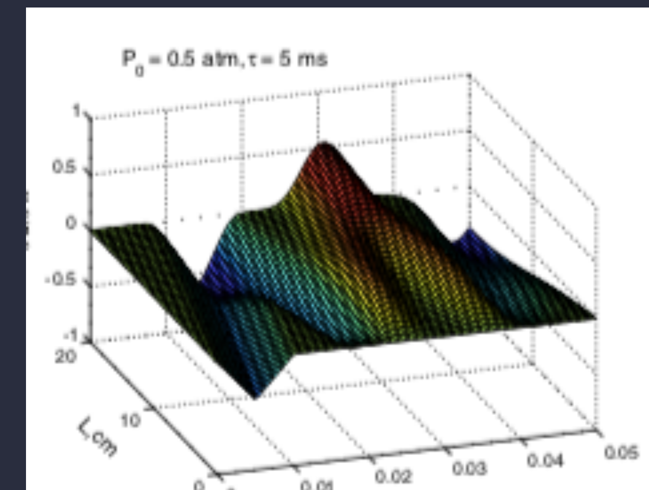
FIG. 6. (Color online) (a) Selected points on lung geometry for surface velocity amplitude comparison with experiment, (b) airway network 2 with terminal impedance specified.

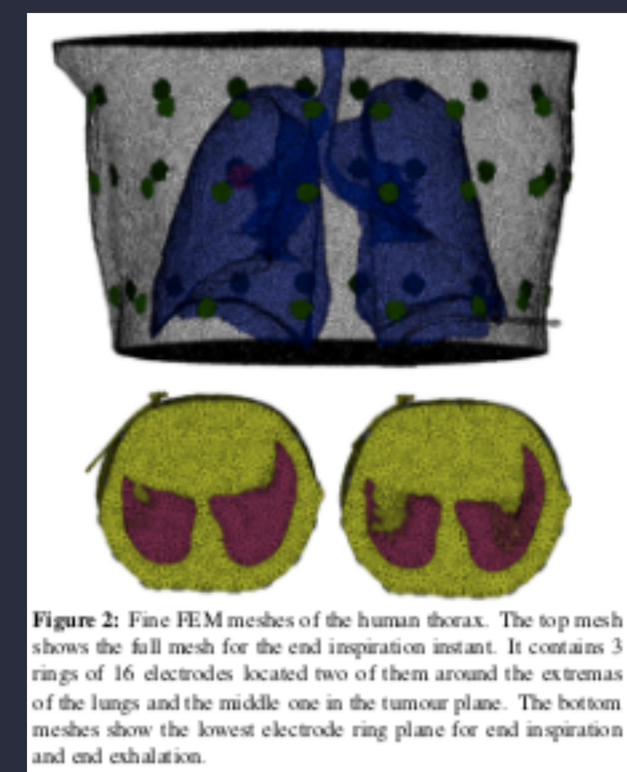
Анализ литературы











Математическая модель

Предположения

- среда ведет себя как жидкость (80% of body)
- среда неподвижна
- полное отражение на границах

Математическая модель

Волновое уравнение для неоднородной среды

$$\frac{1}{c^2(\mathbf{x})} \frac{\partial^2 p(\mathbf{x}, t)}{\partial t^2} = \rho(\mathbf{x}) \nabla \cdot \left(\frac{1}{\rho(\mathbf{x})} \nabla p(\mathbf{x}, t) \right),$$

p(x, t) - pressure, давление воздуха
ρ(x) - плотность ткани / мышц
c(x) - скорость звука

x = [x, y, z] | точка пространства

Математическая модель

Начальные условия

$$p(x, t=0) = 0 \text{ for all } x$$

$$\left.\frac{\partial p(x, t)}{\partial t}\right|_{t=0} = 0$$

Математическая модель

Начальные условия

$$p(x,\ t=0) \quad = 0 \text{ for all } x$$

$$\left.\frac{\partial p(x,\ t)}{\partial t}\right|_{t=0} = 0$$

Граничные условия (отражения + границы пространства)

$$p(x,\ t) = 0 \text{ if } \rho(x) < 0.1 g/cc$$

Математическая модель

Начальные условия

$$p(x,\ t=0) = 0 \text{ for all } x$$

$$\left.\frac{\partial p(x,\ t)}{\partial t}\right|_{t=0} = 0$$

Граничные условия (отражения + границы пространства)

$$p(x,\ t) = 0 \text{ if } \rho(x) < 0.1 g/cc$$

Источник звука

$$p(a,b,c,t) = \sin(2\pi f t)$$

(a,b,c) - положение источника

Математическая модель

Численное приближ. решение

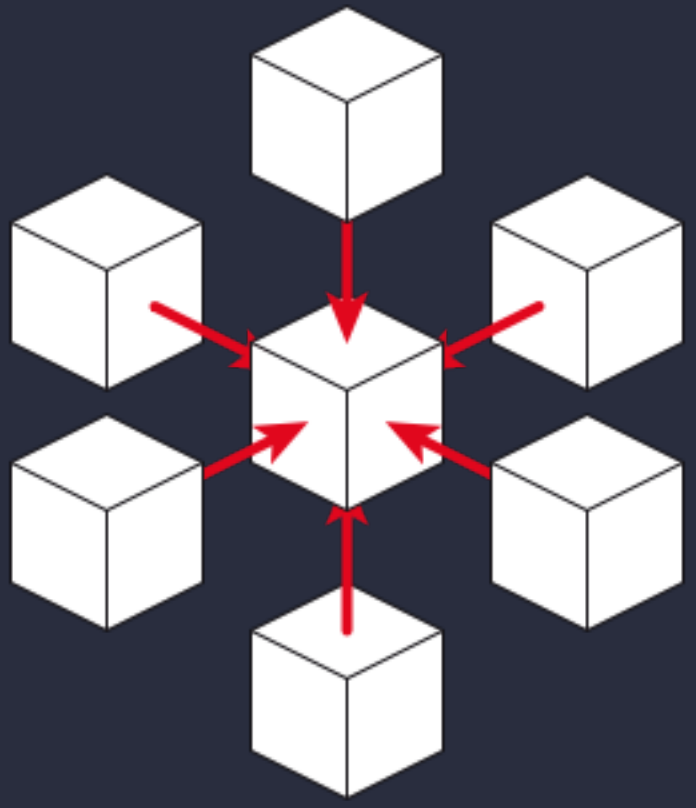
$$
\begin{aligned}
P_{i,j,k}^{m+1} = {} & (2-7.5\kappa_{i,j,k}^2)P_{i,j,k}^m - P_{i,j,k}^{m-1} \\
& + \frac{4\kappa_{i,j,k}^2}{3}\left[P_{i+1,j,k}^m + P_{i-1,j,k}^m + P_{i,j+1,k}^m + P_{i,j-1,k}^m + P_{i,j,k+1}^m + P_{i,j,k-1}^m\right] \\
& - \frac{\kappa_{i,j,k}^2}{12}\left[P_{i+2,j,k}^m + P_{i-2,j,k}^m + P_{i,j+2,k}^m + P_{i,j-2,k}^m + P_{i,j,k+2}^m + P_{i,j,k-2}^m\right] \\
& - \frac{\kappa_{i,j,k}^2}{3\rho_{i,j,k}}\left[(P_{i+1,j,k}^m - P_{i-1,j,k}^m) - (P_{i+2,j,k}^m + P_{i-2,j,k}^m)/8\right](\rho_{i+1,j,k} - \rho_{i-1,j,k}) \\
& - \frac{\kappa_{i,j,k}^2}{3\rho_{i,j,k}}\left[(P_{i,j+1,k}^m - P_{i,j-1,k}^m) - (P_{i,j+2,k}^m + P_{i,j-2,k}^m)/8\right](\rho_{i,j+1,k} - \rho_{i,j-1,k}) \\
& - \frac{\kappa_{i,j,k}^2}{3\rho_{i,j,k}}\left[(P_{i,j,k+1}^m - P_{i,j,k-1}^m) - (P_{i,j,k+2}^m + P_{i,j,k-2}^m)/8\right](\rho_{i,j,k+1} - \rho_{i,j,k-1})
\end{aligned}
$$

$$\kappa_{i,j,k} = (l/h)c_{i,j,k} \qquad l = \Delta t \qquad h = \Delta x = \Delta y = \Delta z$$

Метод конечных разностей, 7-point stencil
производные заменяются разностями

Математическая модель

7-point stencil method



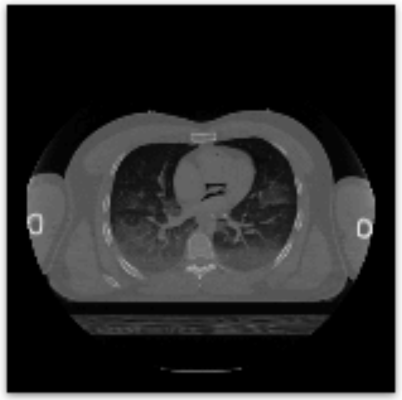
$$\kappa_{i,j,k} = (l/h)c_{i,j,k}$$

$$l = \Delta t$$

$$h = \Delta x = \Delta y = \Delta z$$

Численное приближ. решение.
Метод конечных разностей, 7-point stencil
производные заменяются разностями

Human Visible Project Dataset



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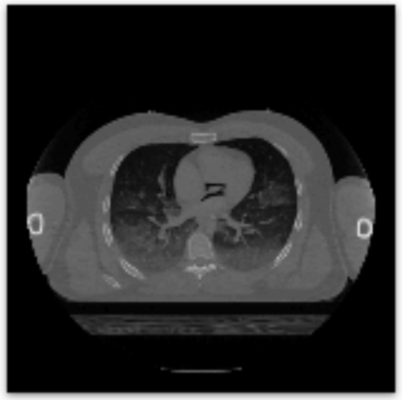

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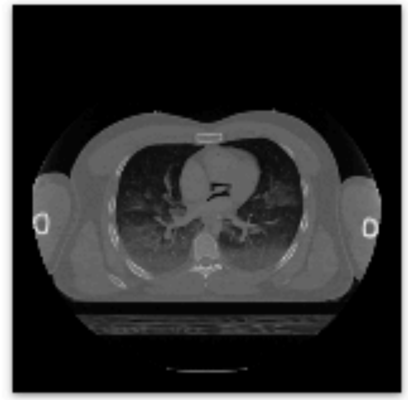

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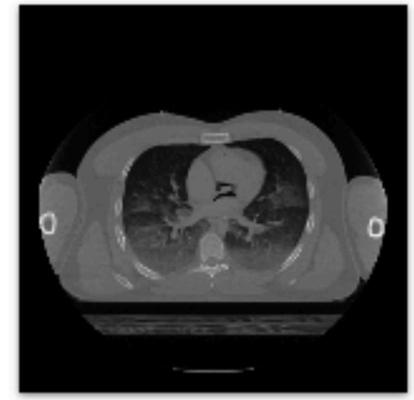

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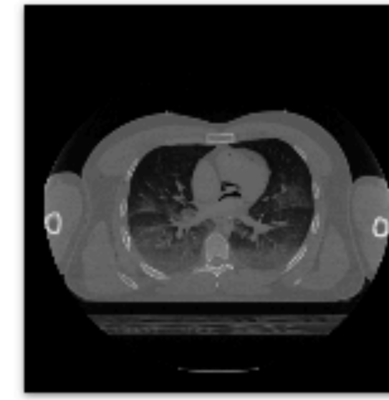

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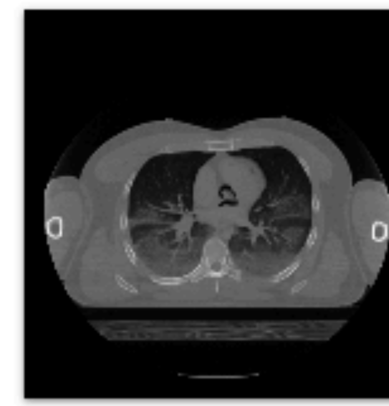

vhm.841.dcm.png

vhm.844.dcm.png

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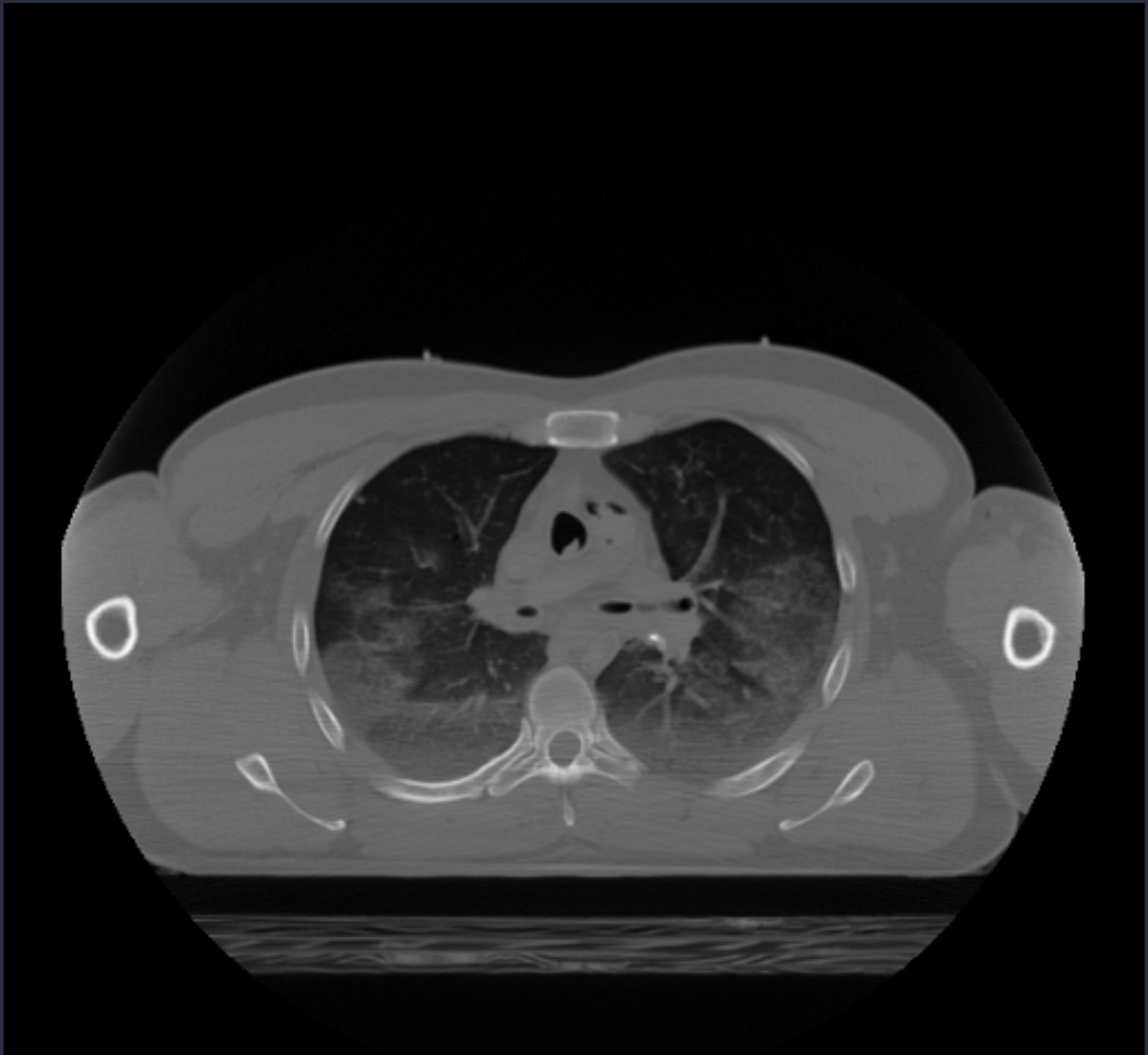
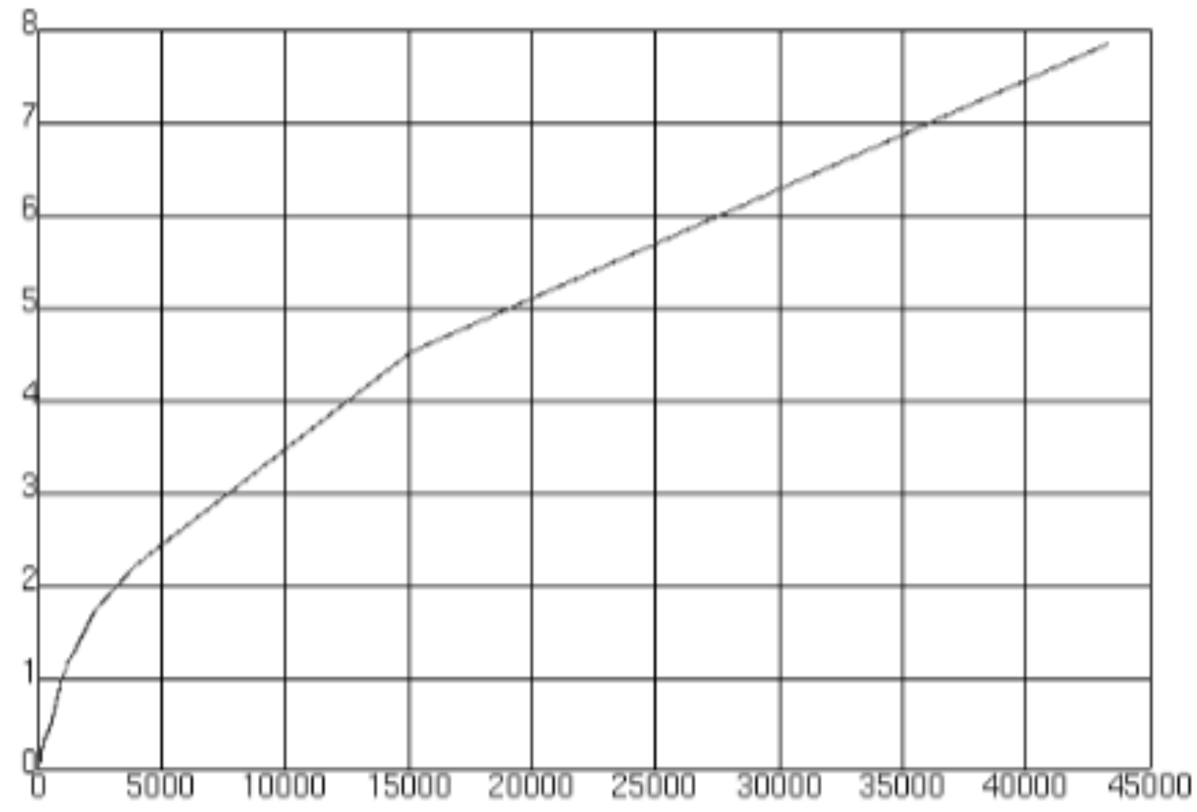
Human Visible Project Dataset



Human Visible Project Dataset

Human Visible Project Dataset



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254	0.292
444	0.438
944	0.895
957	0.945
986	0.980
1024	1.000
1139	1.116
1211	1.142
1504	1.285
1884	1.473
2307	1.707
4000	2.213
15160	4.510
43410	7.850

Задачи работы

1. Анализ литературы
2. Основывать модель на реальных данных
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4. Компьютерная модель
5. Графический интерфейс для управления параметрами модели
6. Оптимизация модели для SIMD,GPU,CUDA
7. Изучение эффектов модели

Компьютерная модель

```python
class LungsModel():
    l_default = 0.065
    h_default = 0.55e-6
    f_default = 110
    # l_default = 0.1
    # h_default = 1
    # f_default = 440

    def __init__(self, L=l_default, H=h_default, F=f_default): ...

    def update_P(self):
        '''
        mb work with flat and then reshape in return
        norm by now, mb add some more optimisations in future, also cuda
        '''

        S = self.P_p.shape[0]
        N = self.P_p.shape[1]

        self.P[2:-2, 2:-2, 2:-2] = 2 * self.P_p[2:-2, 2:-2, 2:-2] - self.P_pp[2:-2, 2:-2, 2:-2]

        Z = np.zeros_like(self.P_p)
        Z[2:-2, 2:-2, 2:-2] = 22.5 * self.P_p[2:-2, 2:-2, 2:-2]

        cell_indeces_flat = np.arange(S * N * N).reshape(S, N, N)[2:-2, 2:-2, 2:-2].ravel().reshape(-1, 1) # vertical vector

        s1_indexes_flat = cell_indeces_flat + np.array([-1, 1, -N, N, -N**2, N**2])      # i±1 j±1 k±1
        s2_indexes_flat = cell_indeces_flat + np.array([-1, 1, -N, N, -N**2, N**2]) * 2  # i±2 j±2 k±2
        s1_values = self.P_p.ravel()[s1_indexes_flat] # each row contains 6 neighbors of cell
        s2_values = self.P_p.ravel()[s2_indexes_flat] # each row contains 6 neighbors of cell
        s1 = np.sum(s1_values, axis=1) # sum by axis=1 is faster for default order
        s2 = np.sum(s2_values, axis=1)

        Z[2:-2, 2:-2, 2:-2] -=   4 * s1.reshape(S-4, N-4, N-4)
        Z[2:-2, 2:-2, 2:-2] += 1/4 * s2.reshape(S-4, N-4, N-4)

        m1 = np.array([1, -1, -1/8, -1/8])
        m2 = np.array([1, -1])

        s3_V_indexes = cell_indeces_flat + np.array([N**2, -N**2, 2*N**2, -2*N**2])
        s3_V_values = self.P_p.ravel()[s3_V_indexes] * m1 # po idee mozhno za skobki kak to vinesti m1 i m2
        s3_V_sum = np.sum(s3_V_values, axis=1)
```

Задачи работы

1. Анализ литературы
2. Основывать модель на реальных данных
3. Математическая модель
4. Компьютерная модель
5. Графический интерфейс для управления параметрами модели
6. Оптимизация модели для SIMD,GPU,CUDA
7. Изучение эффектов модели