



Detection of lung tumor using thermal expansion sensor

N.J.R.Muniraj¹ and K.Sathesh²

¹Tejaa Shakthi Institute of Technology for Women, Coimbatore, India

²Department of ECE, Karpagam College of Engineering, Coimbatore, India.

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ABSTRACT

For every human being there is no life without breathing. Respiration plays a vital role in all living beings. This respiration get affected by many factors. Particularly lung tumor causes major problem during inspiration and expiration. So it is necessary to develop a technique which gives detailed knowledge about the breathing dynamics. The techniques to detect lung tumours in process are invasive in some way whereas 3D modelling of lung will be helpful in detecting lung tumors which is a non-invasive technique. Thus, computer aided modelling of respiratory motion gains importance. In this paper we present an approach to model thermal expansion sensor using MEMS which helps to detect lung tumors in miniature way.

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Introduction

The lung tumor causes major problem during respiration. During inhalation and exhalation tumors will move along with the lungs. It is hard to focus the tumor while applying dose to the affected part and it is important that the dose applied should not affect the normal lung tissue. This becomes challenging in case of lung tumors as organs and tumors move due to respiration. In recent years methods have been developed to explicitly account for respiratory motion in RT such as real-time tumor tracking or gated radiation therapy. To understand the breathing dynamics clearly, it is necessary to model the lung. In medical diagnosis tumors can be detected using various tests but all tests fail to explain lung structure during inhalation and exhalation (Barbara Driscoll 2003) To overcome this problem we use sensor to investigate the lung motion. Figure 1 shows the model of normal and affected lungs. We propose to use MEMS to model thermal expansion sensor which helps to detect tumor in lung during respiration.



Figure 1: Lung model

Modeling approach for lung detection

Lung motion is mainly driven by the process of lung ventilation. The lungs are not moving actively. They are located in the pleural cavity built up by the parietal pleura (adherent to the internal surface of the thoracic cavity and the diaphragm) and the visceral pleura (adherent to the lung surface). Both pleura are joined together at the root of the lung (Rene Werner 2008).

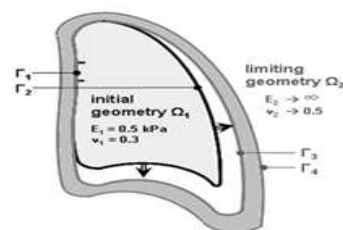


Figure 2: Modelling of lung geometry

Figure 2 shows the illustration of the contact problem considered O1 (inner geometry of lung) represents a lung at expiration which expands due to a negative pressure applied to the lung surface.

Lung expansion is limited by a second geometry O2 (outer geometry of lung) representing the lung shape at end-inspiration. The space enclosed is filled with a liquid and it is subjected to a negative pressure called intrapleural pressure.

Contraction of breathing muscles (diaphragm, outer intercostals) causes the thoracic cavity to expand. This in turn changes the intrapleural pressure which acts as a surface force upon the lung surface.

Thus, lung expands. This movement can be identified using sensor. Figure 3 shows the lungs with tumor on the right side.



Figure 3: Lung with tumors

Tele:

E-mail addresses: njrmuniraj@yahoo.com, sathesh_kce@yahoo.com

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Implementation

Nowadays sensors are used in everyday activities of our life. In this paper Thermal expansion sensor is used to detect tumors which can be implemented using COMSOL multiphysics software.

Sensors

Sensors are used in everyday objects such as sensitive elevator buttons (tactile sensor) and lamps which dim or brighten by touching the base. There are also innumerable applications for sensors of which most people are never aware. Applications include cars, machines, aerospace, medicine, manufacturing and robotics. A sensor is a device which receives and responds to a signal.

A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes. (Gerard 2008) For instance, if the mercury in a thermometer moves 1 cm when the temperature changes by 1 °C, the sensitivity is 1 cm/°C (it is basically the slope Dy/Dx assuming a linear characteristic). Sensors that measure very small changes must have very high sensitivities.

Sensors also have an impact on what they measure; for instance, a room temperature thermometer inserted into a hot cup of liquid cools the liquid while the liquid heats the thermometer. (Subhas Chandra Mukhopadhyay 2009) Sensors need to be designed to have a small effect on what is measured, making the sensor smaller often improves this and may introduce other advantages. Technological progress allows more and more sensors to be manufactured on a microscopic scale as microsensors using MEMS technology. Hence in our project we use thermal expansion sensor which is a microsensor. Microsensor has high speed and high sensitivity compared to macroscopic. (www.ladyada.net/learn/sensors/tmp36.html)

Thermal expansion

When the temperature of a substance changes, the energy that is stored in the intermolecular bonds between atoms changes. When the stored energy increases, so does the length of the molecular bonds (Mitusteru Kimura 2005). As a result, solids typically expand in response to heating and contract on cooling; this dimensional response to temperature change is expressed by its coefficient of thermal expansion.

Thermal expansion is a common method used in the microscale to displace a part of a component, for example in an actuator. In this example model the opposite is required; that is, there should be a minimum of thermal expansion. Such a device could be included in a microgyroscope or any other sensor for acceleration or positioning.

The model consists of two sets of physics: Former deals with a thermal balance with a heat source in the device, originating from Joule heating (ohmic heating).

Air cooling is applied on the boundaries except at the position where the device is attached to a solid frame, where an insulation condition is set and Latter a force balance for the structural analysis with a volume load caused by thermal expansions. The device is fixed at the positions where it is attached to a solid frame. The device is made of the copper-beryllium alloy.

The thermal balance consists of a balance of flux at steady state. The heat flux is given by conduction only. The heat source is a constant heat source of $1 \cdot 10^8$ W/m³. The air cooling at the boundaries is expressed using a constant heat transfer coefficient of 10 W/m² and an ambient temperature of 298 K (Jacob Fraden 2004).

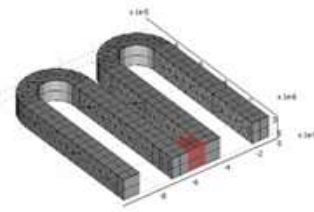


Figure-4: Mesh view of thermal expansion sensor

The stress and strains are well within the elastic region for the material. The expression for thermal expansion requires a strain reference temperature for the copper-beryllium alloy, which in this case is 293 K. In the first part our study we own lung model to explain clear cut view of lung tumors.. To evaluate modeling accuracy we generate patient specific models. Figure 4 shows the mesh view of thermal expansion sensor which is used to define a clear cut model. This second part of the study is based on CT data of thermal expansion sensor of lung tumor Patients. Thermal expansion sensor is modeled with the Required specifications. Temperature variations during respiration shows the presence of tumors. Modeling accuracy is evaluated by simulated patient specific motion patterns of inner lung as observed in the CT data. (www.sciencedirect.com/sciencejournal/01695002)

Comparison of various techniques with MEMS

The following are the various techniques for detection of lung cancer namely Sputum cytology, PET scans, CA 125, T/Tn antigen test, DR 70 and MRI. These techniques are explained clearly in brief way to show how the system helps to detect tumors and how it varies from MEMS.

- Sputum cytology - the microscopic examination of cells obtained from a deep-cough sample of mucus in the lungs can help determine if tests for lung cancer may be required. (Edmund 2009).
- PET Scans may be able to replace the need for a biopsy. Many are now using CT scans to replace X-rays, but the PET scans appear to use less radiation than many CT scans and may provide a more complete diagnostic approach.
- Additional screening tests include CA125-CA125 has become a widely used tumor marker which is measured most often in women with cancers of the reproductive system including the uterus, fallopian tubes and ovaries. Other cancers that may cause abnormal CA125 levels include cancer of the pancreas, lungs, breast and colon. (Carmen Ferreira 2007).



Figure 5: Cross sectional view of lung with tumors

- DR-70 is a simple blood test that screens for 13 different cancers at the same time. It is highly specific and catches cancer long before we would suspect anything was amiss. It runs about \$100. Cancers that can be detected by the test are of the lung, colon, breast, stomach, liver, rectum, ovary, cervix, esophagus, thyroid, and pancreas, and trophoblast and malignant lymphoma. (Barbara Driscoll 2003)
- T/Tn antigen test.- T/Tn Antigen Test developed by Dr. Georg Springer can detect the majority of cancers before any biopsy can pick up the presence of cancer. The T and Tn antigens are proteins on the surface of blood and skin cells and can be

identified by the immune system antibodies. The concentration of these antigens vary depending on the cancer type and stage. A skin prick can predict or indicate the likely development of cancers, even 6-10 years in advance of other tests. The test appears to successfully diagnosis about 94% of lung cancers and 80% of breast cancers. Figure 5 shows the cross sectional view of lung with tumors(Cahill 1994).



Figure 6: Comparative view between normal and affected lung (with tumor)

MRI

A magnetic resonance imaging (MRI) machine uses a large magnet and radio waves to measure the electromagnetic signals your body naturally gives off. (Catherin Westbrook 2005)



Figure 7: MRI image of lung tumors

It makes precise images of the inside of the body, including tissue and fluids. Figure 7 shows the MRI image of lung tumors which can also be used to see if a silicone breast implant has leaked or ruptured. The various techniques which are explained above helps to detect lung cancer but fail to give the 3D view of tumors with motion. (<http://www.medicalnewstoday.com/info/lung-cancer>).

The COMSOL Multiphysics simulation software environment facilitates all steps in the modeling process – defining your geometry, meshing, specifying your physics, solving, and then visualizing your results. The MEMS Module solves problems that couple structural mechanics, microfluidics, and electromagnetic. Built upon the core capabilities of COMSOL Multiphysics, the MEMS Module can be used to address almost all simulations in the microscale domain. Using this COMSOL Multiphysics thermal expansion sensor is designed and we obtain the crystal clear view of lung tumors in miniature way. Due to its microstructure complexity is much reduced. Figure 6 shows the comparative view of normal and affected lung. This affected lung can be detected by the thermal sensor which not only capture the image of tumors but also gives the exact position of tumors in natural way.

Results

The Figure 8 shows the temperature distribution in the device. The heat source increases the Temperature to 323 K from an ambient temperature of 273 K. The temperature varies less than 1/100 of a degree in the device. The displacements vary accordingly, and the model shows that it is possible to study the device using only one unit cell, for example, 1/2 of a U-shaped section. Table 1 shows the X-Y boundary values and Table 2 shows the geometry to draw a U- shaped portion of

Thermal expansion sensor. The edges of the original geometry are shown in black. The deformed shape is exaggerated by a factor of almost 200. Our results are based on a total of 12 lung tumor patients. To evaluate modeling accuracy we identified 20 landmarks in the middle of the lung, 15 landmarks near the lung borders (which are the information bearing structures of the modeling process), and 10 landmarks close to the lung tumor (if existent)for each lung.

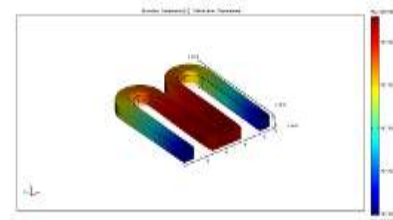


Figure 8: Temperature and displacement of the device

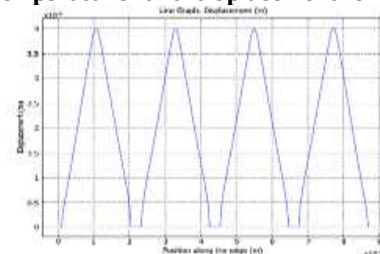


Figure 9 : Lung with single tumor detected using Thermal expansion sensor

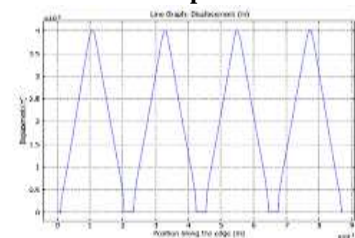


Figure 10-Lung with more tumors detected using Thermal expansion sensor

The Figure 10 shows the displacement of a curve that follows the top inner edges of the device from left to right. It is clear from Figure 9 and 10 that the displacement follows a repetitive pattern along the length of the device. This also supports the hypothesis that 1/2 of a U-shaped section is enough to represent the behaviour of the device.

Conclusions

Outcomes shows that the modelling approach allows estimating lung motion in a reasonable way using thermal expansion sensor. Sensor model approaches helps in focusing on the lung containing even small lung tumor or without tumor. The two U-shaped portion of thermal expansion sensor helps in identifying the position and motion of tumor. Due to its small size complexity is much reduced and the system become more compact. In future work proposed, to detect more number of tumors, thermal expansion sensor can be increased in its shape and size to concentrate on all tumors. Thus, the motion of all tumorous tissue within the lung should be analyzed in more detail on both global and local scale. Corresponding results could be integrated into the modeling approach proposed.

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Table 1: Work plane Settings

X-Y boundary conditions	values
Xminimum	-1.3e-4
Xmaximum	1.3e-4
Yminimum	-0.3e-4
Ymaximum	1.3e-4
Xspacing	1e-5
Yspacing	1e-5

Table 2: To Draw a half U-shaped portion

GEOMETRY	WIDTH	HIEGHT	BASE
Rectangle	1e-5	8e-5	-1e-4
Arc	(-9e-5,8e-5)	(-9e-5,9e-5)	(-8e-5,9e-5)
Line	(-8e-5,1e-4)	(-1e-4,1e-4)	(-1e-4,8e-5)