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The use of computer visualization in the analysis of breathing curves

O Berestneva[1], I Lyzin[1], A Yumasheva[1], O Marukhina[1] and A Trufanov[2]
[1]School of Computer Science & Robotics, National Research Tomsk Polytechnic University, Tomsk, Russia
[2]School of High Technologies, Irkutsk National Research Technical University, Irkutsk, Russia
E-mail: ogb6@yandex.ru

Abstract. Researchers in diverse domains use advanced computer techniques to describe complex entities and processes and impressively visualize those which are often unavailable for direct observation. However, one should emphasize that computer visualization conception implies more than just a convenient, impressive, or high rate information transfer. It also considers a problem of perception, processing, and further cultivation of such important personal qualities as intuition, professional “talent”, and figurative thinking which are of value for experts in any domain. Computer visualization comprises traditionally such sophisticated techniques as computer graphics, animation and virtual reality. Traditionally, computer graphics has delivered strong instruments for creating, processing, and interacting with data representations. Interactive paradigm has led to emergence of a new scope within the problem of artificial intelligence, which is called cognitive computer graphics. The use of cognitive graphics allows physicians, analyzing modest volume of information, to draw significant conclusions. In whole, cognitive graphics forms a separate subfield in medical research. Visualization provides experts with data in current state of patients just to monitor their conditions continuously. In this article, we show the use of computer visualization to study characteristics (including network imprints) of such a common disease as bronchial asthma. The patients were grouped according to influence degree of psychological factors to the occurrence, progression and course stages of the disease. The study focuses on comparison and analysis of the patient’ spirograms and demonstrate presence of physiological and psycho-physiological features among patients with diagnoses of bronchial asthma. In this respect computer visualization provides a solid platform for thorough research and deep analysis in spirometry.

1. Introduction

Bronchial asthma (from Greek. asthma – heavy breathing, smothering) – chronic lung disease affecting people of all age groups. It can occur in the form of single, episodic attacks or has a severe course with asthmatic status and fatal outcome. According to medical statistics, in recent years the incidence of bronchial asthma in most countries has increased significantly. The increase of the disease among young people indicates a continuing trend of increasing development of this disease. The pity fact is that, in spite of scientific advances in the sphere of etiology and the availability of new medicine, the incidence and mortality from bronchial asthma is constantly increasing. This is typical for most countries of the world.

The role of psychosocial, emotional factors in the development of bronchial asthma is estimated by various experts contradictory and the mechanisms are unclear. This is probably due to the fact that all patients with BA are regarded by them as a homogeneous population of people in terms of somatic status, but with different psychological states. In addition, clinicians (pulmonologists, therapists) do not always payattention to the fact that different emotional states and mental disorders bring different physiological reactions in healthy and sick asthma. So the variety of psychological effects causes a variety of psychological and somatic changes in different groups of patients with BA. Because of this it is necessary to study psychological (mental) and social factors in close relationship with clinical ones. On this basis, E. V. Nemerov classified bronchial asthma, taking into account psychological and social factors. The following classification was proposed [1]: BANP - Bronchial asthma is not psychogenic; BASP – Bronchial asthma somatopsychogenic; BAPI – Bronchial asthma psychogenically induced.

Employees of the Siberian State Medical University and Tomsk Polytechnic University during several years were making researches to detect significant differences between groups of patients (physiological and psychological indicators) with bronchial asthma, divided by the degree of influence of psychosocial factors on the occurrence, development and course of the disease [1–6]. To identify hidden patterns in the experimental facts, methods of structural data analysis were used, including methods of scientific visualization [5, 7–11].

The subject of this study is the patients' process of breathing with various forms of bronchial asthma. It is known, bronchial asthma is, first of all, a disease of the respiratory tract, because of it, a study of the patient's reayhing rhythm, the shape of the breathing curve, the presence of apnea, the duration of the inhalation-exhalation cycle, etc. It has great significance [3, 12–15].

Accounting for psychological and social factors, it has some importance [16–21].

2. Materials and methods of research

The experimental data consisted of patients' breathing curves with different types of bronchial asthma and in a group of conditionally healthy people registered with the "MONITOR" instrument (Figure 1) [1].

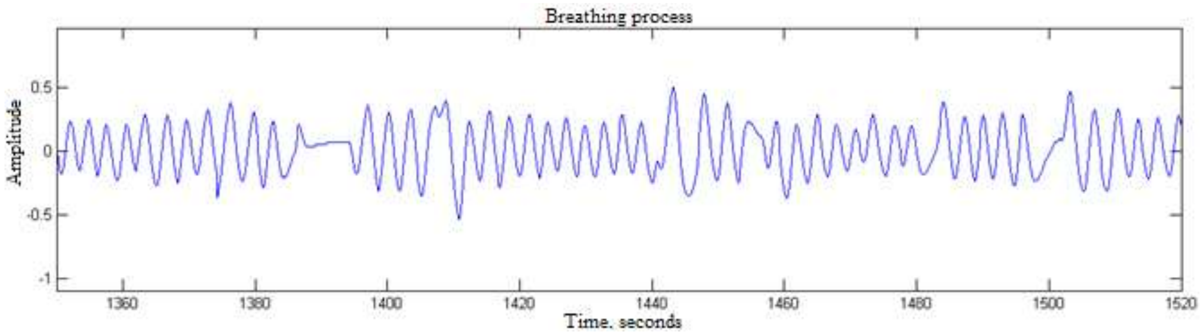

Figure 1. Breathing curve example.

Additionally, breathing curves were converted into networks for further analysis with powerful network instruments. First, the curves were put under digitizing by Engauge Digitizer 4.1 (Figure 2) [22].

Figure 2. Example of digitized volume-time curve.

Second, a conversion code (C#) was developed and applied to realize natural visibility algorithm (NVG, [23]):

```
{
   class LineOfSightMethod
  {
    private List<Point> points;
    private int[,] adjencencyMatrix;
    public LineOfSightMethod(List<Point> points)
    {
      this.points = points;
    }
    public int[,] getAdjecencyMatrix()
    {
      return adjencencyMatrix;
    }
    public void buildAdjecencyMatrix()
    {
       adjencencyMatrix = new int[points.Count, points.Count];
              foreach (Point point in points)
         {
           testPoint(point);
         }
    }
    private void testPoint(Point point)
    {
         adjencencyMatrix[point.getId(), point.getId()] = 0;
         if (point.getId() < points.Count - 1)
         {
            adjencencyMatrix[point.getId(), point.getId() + 1] = 1;
            adjencencyMatrix[point.getId() + 1, point.getId()] = 1;
         }
         if (point.getId() < points.Count - 2)
         {
                    for (int i = point.getId() + 2; i < points.Count; i++)
         {
```

```
                if (testTwoPoints(point, points[i]))
            {
                adjencencyMatrix[point.getId(), i] = 1;
                adjencencyMatrix[i, point.getId()] = 1;
            }
             else
             {
                adjencencyMatrix[point.getId(), i] = 0;
                adjencencyMatrix[i, point.getId()] = 0;
             }
            }
          }
        }
        private bool testTwoPoints(Point point1, Point point2)
        {
          for (int i = point1.getId() + 1; i < point2.getId(); i++)
          {
            Point tempPoint = points[i];
                if (tempPoint.getY() >= (point1.getY() + ((point2.getY() - point1.getY()) *
(tempPoint.getX() - point1.getX()) / (point2.getX() - point1.getX()))))
             {
                return false;
             }
           }
           return true;
         }
       }
     }
```

Third, we used an effective free tool Gephi [24] to visualize and analyze network imprints. The tool delivers structure plots and diverese metrics for each node and link, and for an analyzing graph in whole : The following metrics were taken into account : size (number of vertexes N and edges L in a graph G(V,E), where V is set of vertexes, so that N=|V| and E is set of edges); diameter (the length max ij d(vi,vj) of the "longest shortest path" any two vertices vi,vj, where d(vi,vj) is a shortest path length, we examine the graph diameter D of the largest connected cluster); Clustering coefficient distribution and Average clustering coefficient (Ci for a node i, is a measure of the degree to which nodes in a graph tend to cluster together: Ci=2ei /{ki(ki-1)} , where ki is the number of neighbours of the i'th node, and ei is the number of connections between these neighbours. Average clustering coefficient is noted as $\langle C \rangle = \Sigma\ Ci/N$). Average path length is $\lambda = \langle d(vi,vj) \rangle$.

3. Findings

The frequency spectrum of the breathing curve of each patient was evaluate (Figure 3).

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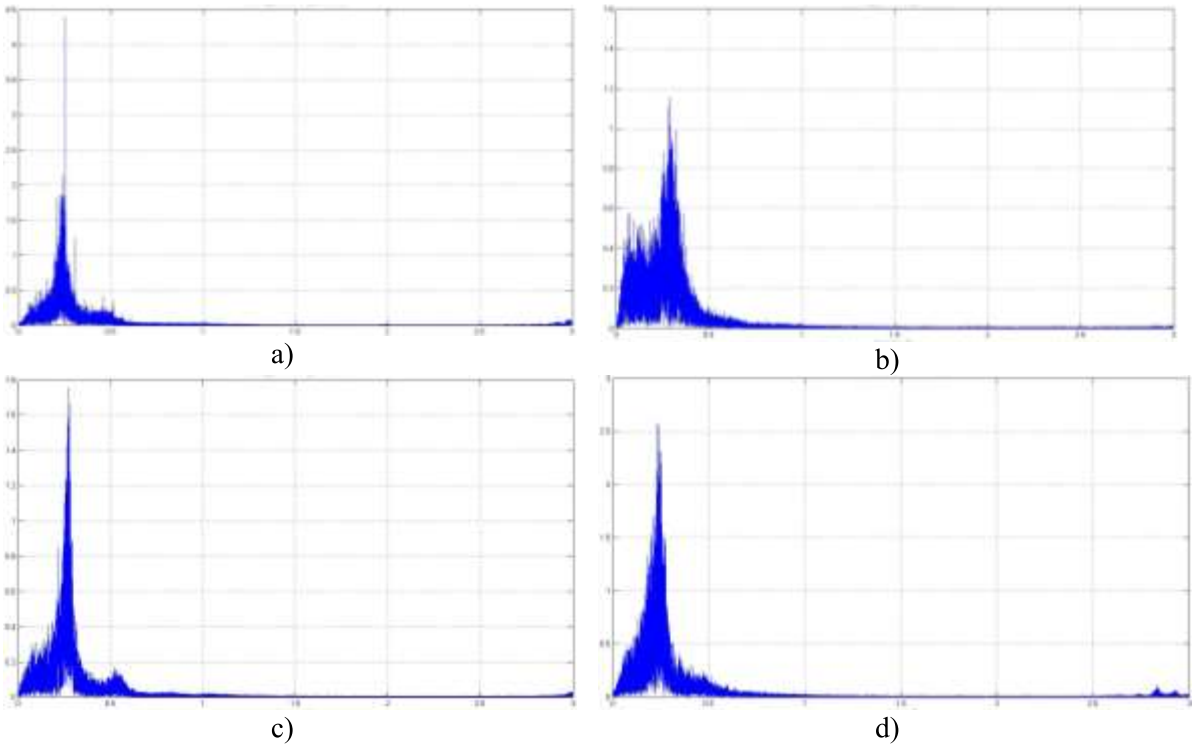


Figure 3. The frequency spectrum of the breathing curve (Hertz) a) healthy person; b) BANP; c) BAPI; d) BASP

The obtained results confirmed by the analysis of spectrograms (Figure 4).

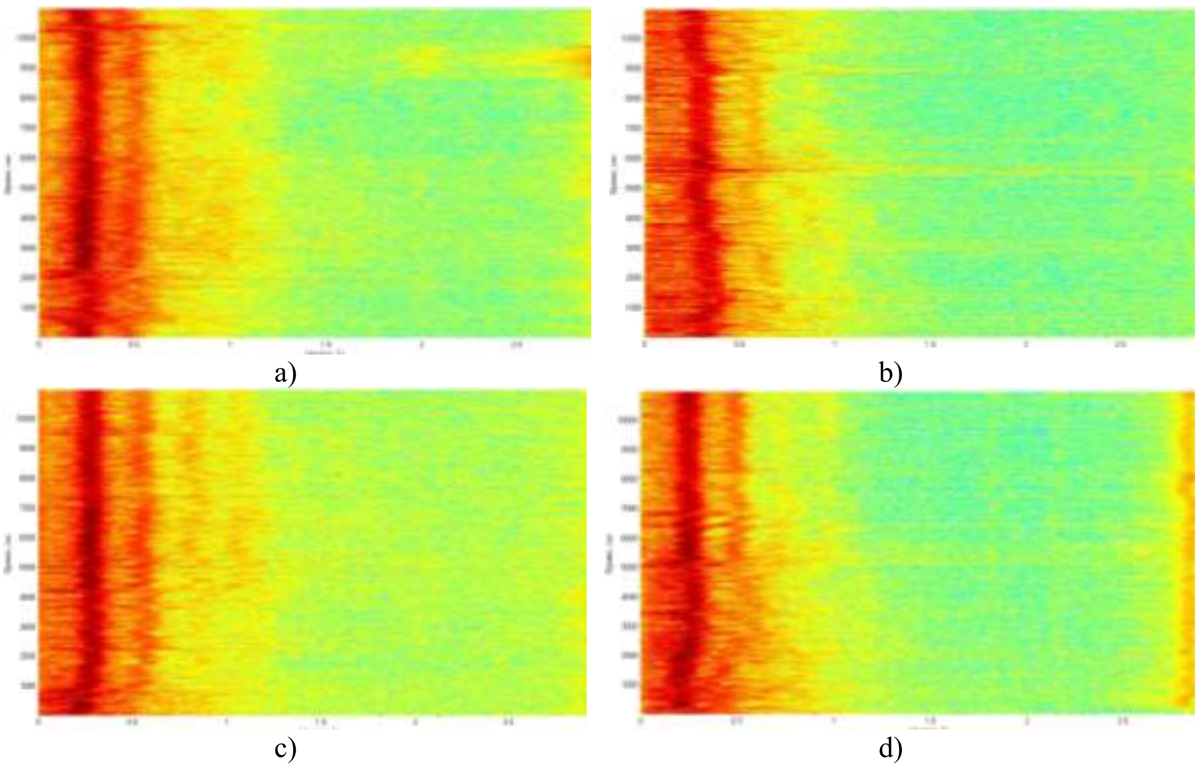


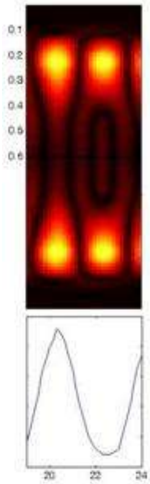
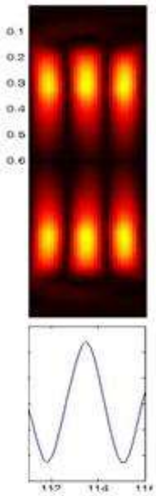
Figure 4. The spectrogram curve of the breath (Hertz): a) healthy person; b) BANP; c) BAPI; d) BASP

4. Discussion

After a careful study of the different groups patients' spectral images of the breathing curves, we managed to isolate several characteristic "single" graphic images (corresponding to one respiratory cycle) for patients with various forms of bronchial asthma and conditionally healthy people. The results are presented in table 1.

Network analysis conveys and enforces spectral image study (table 2).

Table 1."Single" graphic images for different patinen' group.

Diagnosis	Characteristical graphic for one breathing cycle
Almost healthy	
Non-psychogenic bronchial asthma (BANP)	

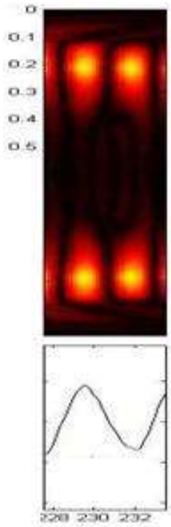
Psychogenic bronchial asthma (BASP)	
Inducted bronchial asthma (BAPI)	

Table 2. Network for differen patient' groups.

NVG algorithm	Almost healthy	BANP	BAPI	BASP
				
D	20	11	34	44
<C>	0.134	0.56	0.35	0.22
λ	7.1	3.7	12.	17.

5. Conclusion

The spectral-time analysis makes it possible to obtain characteristic “single” graphic images of patient’ spirogtams with various forms of bronchial asthma. The table 1 portrays that a healthy person’ spectral image of the volume time curve is noticeably different from almost all images that are typical for patients with various forms of asthma disease. However, patients from the BASP spirogram group are most similar to the spectral image characteristic for the group of “relatively healthy”; there is some similarity with the patient’ spectral images diagnosed with BAPI. The patient’ characteristical spectral image of the BANP breathing curve differs markedly from the others.

Strikingly the network imprints are in balance with the fact that is inferred above (see the table 2).

The results confirm the earlier conclusions [7, 3, 10, 11, 6, 14] about presence of characteristical physiological and psycho-physiological features among patients with diagnoses of BASP, BAPI and BANP.

In this respect computer visualization provides a solid platform for thorough research and deep analysis in spirometry.

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