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A Novel Approach Toward X-RAY Images Classifier

Marcin Woźniak*, Dawid Połap*, Leon Kośmider†‡, Christian Napoli§, Emiliano Tramontana§
*Institute of Mathematics, Silesian University of Technology, Kaszubska 23, 44-100 Gliwice, Poland
Email: Marcin.Wozniak@polsl.pl, Dawid.Polap@gmail.com
†Institute of Occupational Medicine and Environmental Health, Kościelna 13, 41-200 Sosnowiec, Poland
‡School of Pharmacy with the Division of Laboratory Medicine in Sosnowiec,
Medical University of Silesia, Department of General and Analytical Chemistry,
Jagiellońska 4, 41-200 Sosnowiec, Poland
Email: Leon.Kosmider@gmail.com
§Department of Mathematics and Informatics, University of Catania, Viale A. Doria 6, 95125 Catania, Italy
Email: Napoli@dmi.unict.it, Tramontana@dmi.unict.it

***Abstract*—In this paper a novel approach to automatic X-RAY images classification is proposed. The authors propose a solution based on application of Computational Intelligence to assist recognition procedure for medical purposes. Recognition experiments have been performed with the proposed solutions applied on original and authentic X-RAY images from pulmonary diseases clinics, where various diseases were diagnosed. The applied classifier was made to recognize sarcoidosis or cancer over input images. Presented research results are discussed to validate the efficiency of implemented solution.**

I. Introduction

Medicine has always used the latest technology to assist in diagnosis. Decision Support System (DSS) can make the process faster but also improve the decision and help to prevent further health deterioration. Here we would like to discuss a possibility of application of Computational Intelligence to assist diagnosis over input images. The discussed solution aims to analyze X-RAY images and show potential areas of cancer. Indicated potential sites of degenerated tissues of the body will be important clues to the doctor, who will be able to effectively take decisions on how to treat diagnosed patients. In this process we have implemented Computational Intelligence (CI). Proposed solution imitates human intelligence, since similarly to the doctor applied CI methods search for diseased tissues over input X-RAY image. The methods imitate human evaluation using simplified criterion to evaluate pixels in the picture.

CI methods are applicable in various DSS, where they assists in efficient sophisticated problems tackling. CI methods find their applications in positioning, simulation, optimization, recognition, control and management (see [1], [2], [3], [4], [5], [6], [7]). Where CI powers the resolution of complicated differential and integral equations used in positioning queueing systems and workflow management, as presented in [8] or [9]. In [10] and [11] CI efficacy in positioning dynamic systems constructed of many co-working subsystems was discussed. CI has been also applied in innovative games [12], [13] and decision making systems [14], [15].

A. Related Works

CI has many methods that may be useful in the process of knowledge and information assembling for medical DSS. One of these processes is 2D image recognition, where dedicated CI systems may help to classify input objects. However, this is a non-trivial operation and the efficiency is of paramount importance. This paper describes an application of CI methods, in particular dedicated versions of Firefly Algorithm (FA) and Cuckoo Search Algorithm (CSA), as a dedicated solutions that creates a medical X-RAY input image recognition system. These methods were efficiently applied for various purposes: image processing and compression [16], [17], [18], [19] and [20]; threshold selection [21]; Short Term Load Forecasting [22]; dynamic multidimensional knapsack problems solving [23]; stochastic and reliability optimization [24]; queueing systems positioning [3], [25]; and ECG signals modeling for neural network DSS [26]. Finally these methods have been applied in image processing for object recognition what was improved for human like intelligence in [27]. In this paper, using our experience from cited research, we present applications of CSA and FA in medical DSS.

II. Medical Background of the Research

During the last century lungs diseases (cancer or some other lifestyle diseases) have become, from the rare disease a pandemic of the 20th and 21th century. Because if the fact that smoking was a rare habit before 20th century, reports on lung carcinoma were sporadic. Then the number of lung cancer diagnoses increased in XXs as a result of the increase of cigarettes consumption, which in turn was connected with progress in tobacco marketing and what's seems to be even more important the introduction of cigarette smoking machine in 1880s. This dramatically increased the production of cheaper cigarettes. It is common knowledge, that the current increase in lung cancer events is preceded by rise in cigarette consumption $20 - 30$ years earlier. The lung cancers in 2008 were a cause of 0.38 million of death in European Union region and 1.4 million worldwide according to *http://data.euro.who.int/*. It is 3.9% and 2.4% of the total number of deaths respectively and this fatal trend is increasing. In Poland in 2012 it was 22000 deaths which responds to 5.9% of all deaths, and 15% of all cancers related deaths including 8% of mens and 3.52% of women deaths. Up to

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date lung cancer kills more women than the breast cancer (3.05%), even if the morbidity on that disease is 3 times higher [28]. Important role in cancerogenesis play sex, lifestyle, age and work. Most of the patients with lung carcinoma are men, but among women the morbidity of that sickness increases, especially in younger age. But in most cases these cancer increase with age and has its maximum in $60-70$ years of live [28].

Ground-braking publications, which link tobacco smoking with lung cancer were published in the middle of 20th century. One of the most important is Surgeon Generals Report on Smoking and Health [29], where it was reported that smoking is most probably responsible for carcinoma of the lung and other health problems. The Report was a first step to beginning of modern public health efforts of tobacco control. Nowadays the active smoking is the most frequent cause of 90% men and 80% women lung cancers or other lungs diseases. People who smoke are $15-30$ times more likely to be diagnosed with lung cancer and this risk depends on the intensiveness and duration of smoking. Tobacco smoke consist of more than 5600 chemicals, including more than 60 identified as carcinogenic for human. The most recognized tobacco compound is nicotine [30], [31]. The compound is responsible for an addiction to tobacco, but has no carcinogenic properties proven. Now for people who are unwilling, or unable to quit smoking on the market appeared electronic cigarettes. The devices in contrast to classic cigarettes contains nicotine dissolved in solution and do not involve combustion during transform it into vapor [32], [33]. The aerosol inhaled by a user have trace amount of carcinogens, only in case of formaldehyde in some device settings, which can by similar in level to the tobacco smoke [34]. The device is a promising solution to decrease smoking related diseases in populations, but also rise a controversy about the harm reduction related to tobacco.

The second leading cause of lung cancer or serious lungs diseases after tobacco smoking is radon. High concentrations of that radical increased risk of lung cancer in miners. Inhaled radon can have a carcinogenic effect due to increase exposition of lung cells for alpha particles. From the other environmental factors we can name secondhand smoke exposure and asbestos. There is no doubt, that environmental exposure of nonsmokers to tobacco increases the risk of lung disease, by an increased concentration of tobacco specific carcinogens in the body fluid [28].

Among patients with a diagnosed lung cancer in $2000-2002$ in Poland 1-year survival rates for men and women were 34.7% and 41.6% respectively. While 5 years survival rates were 10.8 and 15.7% for men and women respectively. 5 years survival rate in USA is about 15% and 11% on average in the European Union. These numbers depend on the tumor stage. Most of the people who survive 5 years from the diagnose had diagnosed lung cancer in early stage. People with diagnosed tumors on first stage have $43-50\%$ chance to survive 5 years. With tumors in 2nd stage the chance of survive drops to $25-36\%$, in 3rd stage to $7-19$ and eventually in 4rd stage it reaches 2%. Unfortunately only 16% of diagnosed cancers, are the once in 1st or 2nd stage [35]. One of the most important reason for that situation is a fact, that lung cancer do not have any specific symptoms in early stage. Ease of selecting individuals with increasing risk of cancer and the small efficiency of treating people with late stage of lung cancer promote research which will help in find effective screening for that sickness.

An intelligent chest radiography may be a perfect way in the detection of lung diseases in its early stage. This method is very beneficial for various medical centers, thanks to its widely positive aspects in many different areas (very cheap test, simple to realize, low rate of false positive findings). In the future, these methods may improve the sensitivity of chest radiography in the detection of early stage lung cancer by introduction of some dedicated CI methods. Application of precise and efficient methods may increase the possibility of early diagnosis, and therefore save many lifes. In this paper we would like to discuss a novel approach to lungs diseases. Presented solution simulates human expert medical examination of X-RAY images. Similarly to human experts implemented methods using developed criterion search over input image for diseased tissues represented in pixels of special properties.

III. Toward Automatic Classification

Machines can assist in the process of classification. However this recognition must be based on efficient algorithms. We propose a novel attempt to diagnose medical X-RAY images. Any digital image $\mathcal{I}$ consist of points (pixels) $\mathbf{x_i} = (x_{i,1}, x_{i,2})$, each having a position and special properties. All these features give us peculiar information crucial for classification. Using it one can identify somebody or a special input [36], [37], [38], [17] and [27]. Here, CI solution will be applied to search for areas of potentially degenerated tissues of the human body over the input X-RAY image. Dedicated CI method is used to point where are the cancer or degenerated tissues. As we can see in the preliminary research results, dedicated versions of CSA and FA have good efficacy and high potential of improvement.

A. *Firefly Algorithm for medical X-RAY images recognition*

Firefly Algorithm (FA) maps the behavior of fireflies while searching for the best partner into the process of optimization. The method describes fireflies and environment conditions that are characterized by specific features, which are modeled with numerical values: way of flashing (I_{pop}–light intensity factor), way of moving (μ–factor for random motion of individual) and perception of other individuals (β_{pop}–factor for attractiveness), light absorption coefficient γ. In real life the fireflies that do not find a proper partner can die, and their place in the population is taken by new individuals. This phenomena was mapped by introduction of $best\_ratio$ coefficient, which represents the number of surviving individuals in the algorithm. Moreover in the applied FA model, the following assumptions are used:

1) Points in X-RAY image are presented to flying fireflies for evaluation.
2) Because fireflies are unisex they can attract each other.
3) Fireflies will move toward brighter one measuring the distance between them.
4) If there is no attractive firefly within the range population move randomly.

Each pixel $\mathbf{x_i}$ in input X-RAY image $\mathcal{I}$ is presented for flying fireflies in the algorithm. The fireflies move according to mathematical model over the input image to find best solution for the task.

1) Graphix Firefly Algorithm: In the presented Graphix Firefly Algorithm (GFA) solution was applied a dedicated version for medical X-RAY images. We are modeling some phenomena of the fireflies swarm to obtain a live organism to perform recognition task. Distance between any two fireflies i and j is defined as

$$r_{ij}^t = \|\mathbf{x_i}^t - \mathbf{x_j}^t\| = \sqrt{\sum_{k=1}^{2}(x_{i,k}^t - x_{j,k}^t)^2}, \quad (1)$$

where the symbols are: $\mathbf{x_i}^t$, $\mathbf{x_j}^t$–pixels in the image $\mathcal{I}$ in t iteration, $x_{i,k}^t$, $x_{k,j}^t$–k-th components of spatial coordinates of $\mathbf{x_i}^t$ and $\mathbf{x_j}^t$ that describe position (pixel in the classified image) measured in t iteration. Attractiveness of firefly i to firefly j decreases with increasing distance and is proportional to intensity of light according to

$$\beta_{ij}^t(r_{ij}^t) = \beta_{pop} \cdot I_{pop} \cdot e^{-\gamma \cdot (r_{ij}^t)^2}, \quad (2)$$

where the notations are: $\beta_{ij}^t(r_{ij}^t)$–attractiveness of firefly i to firefly j in t iteration, r_{ij}^t–distance defined in (1), γ–light absorption coefficient mapping natural conditions. Fireflies movements are based on conditioned distance to other individuals surrounding it. A firefly will go to the most attractive one, measuring intensity of flicker over the distance between them, this process is mapped in (2). Using this information, CI remaps the natural behavior of real life organisms. A firefly i motion toward a more attractive individual j is performed according to

$$\mathbf{x_i}^{t+1} = \lfloor \mathbf{x_i}^t + (\mathbf{x_j}^t - \mathbf{x_i}^t) \cdot \beta_{ij}^t(r_{ij}^t) + \mu^t \cdot e_i^t \rfloor, \quad (3)$$

where the notations are: $\mathbf{x_i}^t$, $\mathbf{x_j}^t$–points in X-RAY image $\mathcal{I}$, $\beta_{ij}^t(r_{ij}^t)$–attractiveness defined in (2), r_{ij}^t–distance between fireflies defined in (1), γ–light absorption coefficient mapping natural conditions, μ^t–coefficient mapping natural random motion in each iteration t, e_i^t–vector randomly changing firefly position. In the model was applied special condition over the movement. We define motion only over integer numbers using $\lfloor \cdot \rfloor$, what is efficient for GFA as it classifies points using their position which is measured in integer numbers only. Using these facts, we have built GFA to recognize degenerated tissues in the human body, what is performed according to Algorithm 1.

Algorithm 1 GFA to search for degenerated tissues in the human body X-RAY image

Define coefficients: I_{pop}, μ, β_{pop}, γ, $best\_ratio$, number of $fireflies$ and $generations$ in the algorithm,
Define fitness function for the algorithm – properties for degenerated tissues diagnosis according to (7),
Create at random initial population of $fireflies$ in $\mathcal{I}$,
t:=0,
while $t \leq generations$ **do**
  Calculate r_{ij}^t in current population P using (1),
  Calculate $\beta_{ij}^t(r_{ij}^t)$ in population P using (2),
  Evaluate $fireflies$ in population P using (7),
  Create derived population O: move $fireflies$ towards closest and most attractive one using (3),
  Evaluate all $fireflies$ in derived population O using (7),
  Replace $best\_ratio$ of $fireflies$ from population P with $best\_ratio$ of $fireflies$ from derived population O, the rest take at random,
  Rest of $fireflies$ take at random,
  $t++$,
end while
Best $fireflies$ from the last population P are recognized degenerated tissues in the human body.

B. Cuckoo Search Algorithm for medical X-RAY images recognition

Cuckoo Search Algorithm (CSA) is very efficient gradient free optimization technique, where Gauss distribution is applied. CSA is mapping behavior of cuckoos flying and looking for nest to lay an egg. They try to choose optimal hosts. When hosts come home they either get rid of intruder egg or just simply accept the new situation. This process was implemented in medical image classifier with assumptions:

1) Points in X-RAY image are potential host nests, that are of interest to flying cuckoos.
2) Each cuckoo has only one egg to lay.
3) Total amount of flying cuckoos is constant.
4) Best nests containing egg (pixels of highest classified quality) will be transferred to next generation.
5) Rest of cuckoo population will be taken at random within all given image pixels.
6) Hosts may find intruder's egg with $1 - p_\alpha \in \langle 0, 1 \rangle$ probability and get rid of it. In this case a new cuckoo is placed randomly in the image.

In Graphix Cuckoo Search Algorithm (GCSA), egg or host nest is similar. All these are the same, because the algorithm is classifying points in input image. First these pixels are presented to flying cuckoos. Then these cuckoos are lying eggs in selected pixels, therefore finally we call them eggs. Then decision is taken by hosts to drop the egg or not. That is why these tree names are simultaneously changed.

1) Graphix Cuckoo Search Algorithm: In each round of GCSA the best points are transferred to next generation, what is represented in $best\_ratio$ coefficient. This is to simulate that only the best birds live long enough to have offspring. The rest of population is taken at random to maintain constant level of cuckoos. In every generation we only model motion over the image with particular formula

$$\mathbf{x_i}^{t+1} = \lfloor \mathbf{x_i}^t + \mu \cdot L(\beta, \gamma, \delta) \rfloor, \quad (4)$$

where the notations in t iteration are: $\mathbf{x_i}^{t+1} = (x_{i,1}^{t+1}, x_{i,2}^{t+1}) \in \mathcal{I}$ – next solution in GCSA, μ – length of step in random walk based on normal distribution $N\left(\frac{\gamma}{cuckoos}; 0, 1\right)$, L($\beta$,$\gamma$,$\delta$) – Lévy flight for a given step length β, δ – length of minimum step for random walk and γ – scaling parameter for Lévy flight. Classification of image points is based on (4), where $\lfloor \cdot \rfloor$ is applied as $\mathbf{x_i} \in \mathcal{I}$ has position measured only in integer values.

GCSA classification uses a concept of random walks, what helps to perform non local search in various images. Lévy flight is also called random walk, in which length of particular step has value determined with special probability distribution. In GCSA Lévy flights are made isotropic in random directions, according to formula

$$L(\beta,\gamma,\delta)=\begin{cases}\sqrt{\frac{\gamma}{2\pi}}\frac{exp[-\frac{\gamma}{2(\beta-\delta)}]}{(\beta-\delta)^{\frac{3}{2}}}, & 0<\beta<\delta<\infty\\ 0, & \text{other}\end{cases}, \quad (5)$$

where the notations mean similar to (4). Finally hosts decision is modeled with equation

$$H(\mathbf{x_i}^{t+1})=\begin{cases}1-p_\alpha & \text{drop the egg}\\ p_\alpha & \text{the egg stays}\end{cases}, \quad (6)$$

where the symbols are: $H(\mathbf{x_i}^{t+1})$ – decision taken by hosts about intruder egg $\mathbf{x_i}^{t+1}$, $p_\alpha \in \langle 0,1\rangle$ – chance of each cuckoo egg to stay. The GCSA to recognize degenerated tissues in the human body is presented in Algorithm 2.

Algorithm 2 GCSA to search for degenerated tissues in the human body X-RAY image

Define all coefficients: $p_\alpha \in \langle 0,1\rangle$, β, γ, δ, $best\_ratio$, number of $cuckoos$ and number of $generations$ in the algorithm,
Dedicated criterion function: brightness of pixels according to (7),
Create at random initial population in the image,
t:=0,
while $t \leq generations$ **do**
  Move $cuckoos$ according to (4) and (5),
  Hosts decide if the eggs stay or no – decision according to (6),
  Sort points (cuckoos) according to the value of criterion function,
  Evaluate population and take $best\_ratio$ of them to next $generation$,
  Rest of $cuckoos$ take at random,
  $t++$,
end while
Best $cuckoos$ from the last $generation$ are recognized degenerated tissues in the human body.

C. Simplified fitness function for classification purposes

In our classifier, the algorithms presented in Sections III-A and III-B were applied to search for degenerated tissues in the human body. A population of fireflies or cuckoos, each representing $\mathbf{x_i} \in \mathcal{I}$, is simulated in order to move from point to point and search for diseases. Searching is based on a simple fitness function that reflects the brightness of each pixel

$$\Phi(\mathbf{x_i})=\Phi((x_{i,1},x_{i,2}))=\begin{cases}0.1\ldots 1 & \text{saturation}\\ 0 & \text{other}\end{cases}, \quad (7)$$

where notation $\Phi(\mathbf{x}_i)$ denotes quality of the evaluated pixel. This measure reflects a value in the scale from 0.0 to 1.0, where saturation of the filtered $\mathbf{x_i} \in \mathcal{I}$ changes from black to white. Mainly in X-RAY images the degenerated tissues in the human body are of changed features. These features are visible in the images, representing pixels are mainly more bright than these representing healthy tissues. Therefore using GFA or GCSA with fitness function (7) on the X-RAY image we are able to classify the input.

IV. Research results

In the research, simulations were performed for:

- GFA method: 100 fireflies in 10 generations with set coefficients: $\beta = 0.3$, $\gamma = 0.3$, $\mu = 0.3$ and $best\_ratio = 30\%$.
- GCSA method: 100 cuckoos in 10 generations with set coefficients: $\beta = 0.5$, $\gamma = 0.3$, $\mu = 0.25$, $\delta = 0.2$ and $best\_ratio = 30\%$.

Due to limited space in the paper let us present only some classification results. The images are original, real medical X-RAY images from various clinics in Poland collected during research project, therefore we covered some parts of images containing personal data of the examined patients or cut these parts from the images. Moreover, due to various medical equipment used in the clinics, the presented images are of different shapes and quality. We have examined various diseases and the preliminary research results are very promising. In this section we would like to discuss the CI recognition over tree very common lungs diseases: cancer, sacroidosis and pneumonia. In all the images, in the first place we can GFA recognition and in the second position GCSA recognition.

In Fig. 1 is presented recognition over cancer tissues in man lungs, the presented examinations show how serious medical example it is. Cancer is unfortunately very dangerous for humans and is killing many people each year. Therefore proper diagnosis can help to prevent more deaths. Both methods recognized cancer tissues showing their locations in the body. However GCSA is of better precision, recognition gave better shape of the degenerated tissues. In Fig. 2 is presented recognition over sacroidosis tissues in man lungs. In Fig. 3 is presented recognition over pneumonia in woman lungs.

A. Conclusions

The presented system for image classification allowed us to diagnose degenerated tissues in the human body. The ideal lung diseases screening method should be relatively sensitive, widely available and have good specificity. Up to date digital radiography, which have higher resolution especially combined with the Artificial Intelligence image recognition should increase the sensitivity for a lung cancer screening.

The presented solutions are promising and with introduction of dedicated filtering functions, which the authors are currently working on, would become a very efficient tool to help lungs diseases diagnose. However, introducing a special recognition function is non-trivial task, it is the most sensitive part of the classifier. We must define a special, different functions for each disease, i.e. cancer, sarcoidosis, pneumonia, etc. Here a neural network attempt (similar to [39], [40], [41] or [42]) or dedicated fuzzy ruled systems (similar to [43] or [44]) will be applied.

V. Final Remarks

There are only two ways to decrease the mortality from lung cancers and other diseases. First is to decrease the use of tobacco. It can be done by tighten the smoke-free policies or increase the interest in tobacco harm-reduction strategies. High hopes for that gives electronic cigarettes and

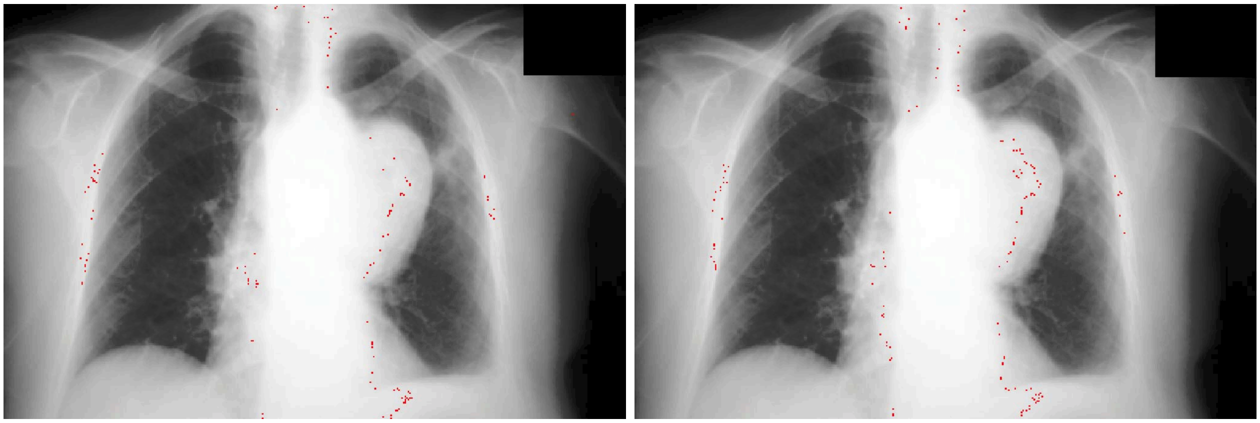

Fig. 1. GFA and GCSA recognition over cancer tissues in left part of the lungs on the original image from the X-RAY apparatus

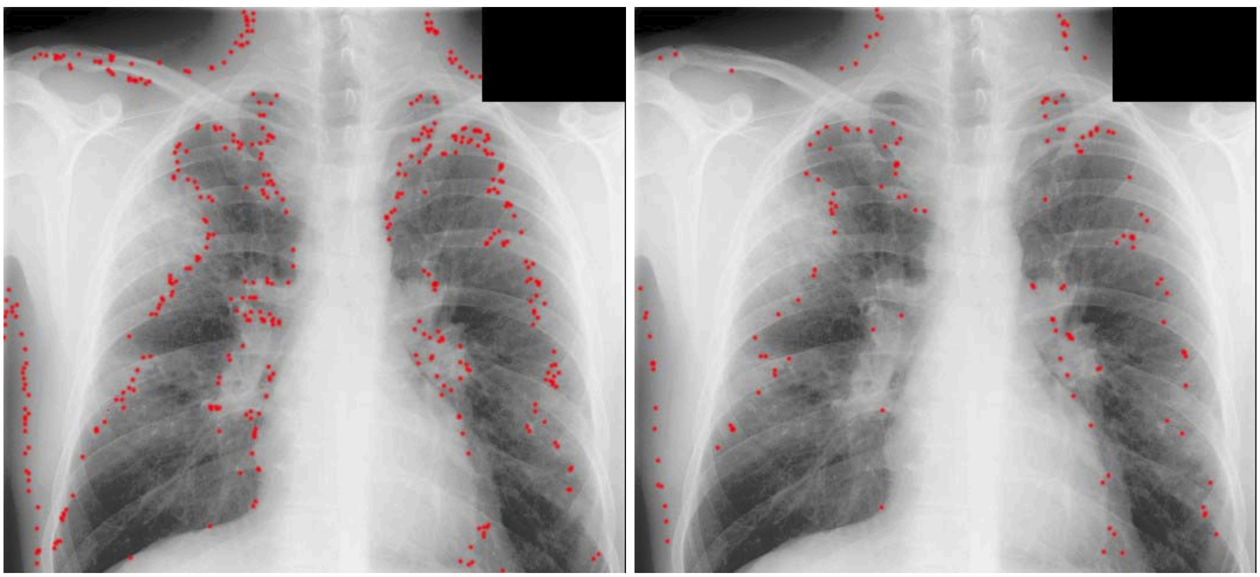

Fig. 2. GFA and GCSA recognition over sacroidosis on the original image from the X-RAY apparatus

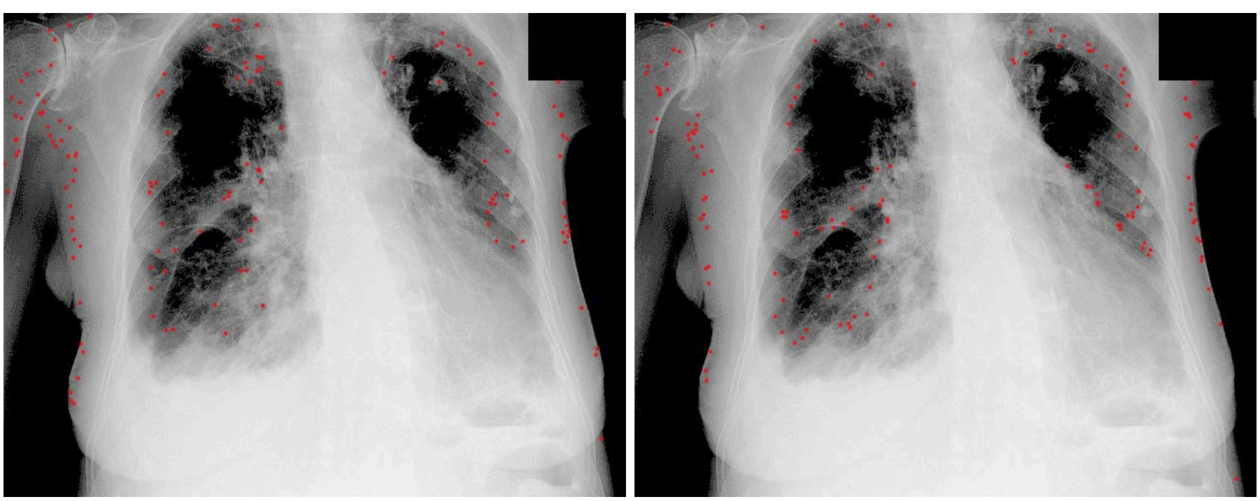

Fig. 3. GFA and GCSA recognition over pneumonia on the original image from the X-RAY apparatus

other nicotine product, with reduced amount of carcinogenic compounds [32]. Other is to improve detection systems. Dedicated intelligent systems would allow to notice all possible negative lifestyle outcomes as fast as possible and minimize the potential harmful to the population. In that case we do not have an effective tool to do it with lung cancerogenesis risk. Therefore development of new scientific tools which allow relatively fast and precise diagnosis are needed. Because there is no recommended, cost-effective and widely confirmed method which allows to detect lung diseases in early stage in the same time as we try to manage with worldwide tobacco epidemy we should try to find the new screening methods for one of the most dangerous cancer related diseases.

We present a novel approach to lungs diseases classification based on the application of FA and CSA. Where CI methods are used to help in decision making over medical X-RAY images. Research results for sample images show efficacy and high precision. The presented methods can work as part of various classifier for medical purposes. This feature makes them promising tools for AI recognition systems and dedicated image classifiers. Applied CIA methods are precise and easy to implement. Hence, presented a novel classifier approach is efficient and precise with a possibility to improve.

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References

[1] F. Bonanno, G. Capizzi, A. Gagliano, and C. Napoli, "Optimal management of various renewable energy sources by a new forecasting method," in *International Symposium on Power Electronics, Electrical Drives, Automation and Motion - SPEEDAM'2012*. IEEE, 2012, pp. 934–940.

[2] M. Gabryel, R. K. Nowicki, M. Woźniak, and W. M. Kempa, "Genetic cost optimization of the $GI/M/1/N$ finite-buffer queue with a single vacation policy," *Lecture Notes in Artificial Intelligence - ICAISC'2013*, vol. 7895, pp. 12–23, 2013, DOI: 10.1007/978-3-642-38610-7_2.

[3] M. Woźniak, "On applying cuckoo search algorithm to positioning $GI/M/1/N$ finite-buffer queue with a single vacation policy," in *Proceedings of the 12th Mexican International Conference on Artificial Intelligence - MICAI'2013*. 24-30 November, Mexico City, Mexico: IEEE, 2013, pp. 59–64, DOI: 10.1109/MICAI.2013.12.

[4] M. Woźniak, W. M. Kempa, M. Gabryel, R. K. Nowicki, and Z. Shao, "On applying evolutionary computation methods to optimization of vacation cycle costs in finite-buffer queue," *Lecture Notes in Artificial Intelligence - ICAISC'2014*, vol. 8467, pp. 480–491, 2014, DOI: 10.1007/978-3-319-07173-2_41.

[5] P. Dziwinski, L. Bartczuk, and J. Starczewski, "Fully Controllable Ant Colony System for Text Data Clustering," *Lecture Notes in Computer Science - ICAISC(SIDE-EC)'2012*, vol. 7269, pp. 199–205, 2012, DOI: 10.1007/978-3-642-29353-5_23.

[6] P. Dziwinski, L. Bartczuk, A. Przybyl, and E. Avedyan, "A New Algorithm for Identification of Significant Operating Points Using Swarm Intelligence," *Lecture Notes in Artificial Intelligence - ICAISC'2014*, vol. 8468, pp. 349–362, 2014, DOI: 10.1007/978-3-319-07176-3_31.

[7] B. Nowak, R. K. Nowicki, M. Woźniak, and C. Napoli, "Multi-class nearest neighbor classifier for incomplete data handling," *Lecture Notes in Artificial Intelligence - ICAISC'2015*, vol. 9119, pp. 469–480, 2015, DOI: 10.1007/978-3-319-19324-3_42.

[8] C. Napoli, G. Papplardo, and E. Tramontana, "Improving files availability for bittorrent using a diffusion model," in *IEEE 23nd International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises - WETICE'2014*. IEEE, 2014, pp. 191–196.

[9] M. Woźniak, W. M. Kempa, M. Gabryel, and R. K. Nowicki, "A finite-buffer queue with single vacation policy - analytical study with evolutionary positioning," *International Journal of Applied Mathematics and Computer Science*, vol. 24, no. 4, pp. 887–900, 2014, DOI: 10.2478/amcs-2014-0065.

[10] M. Woźniak, "Fitness function for evolutionary computation applied in dynamic object simulation and positioning," in *IEEE SSCI 2014: 2014 IEEE Symposium Series on Computational Intelligence - CIVTS 2014: 2014 IEEE Symposium on Computational Intelligence in Vehicles and Transportation Systems, Proceedings*. 9-12 December, Orlando, Florida, USA: IEEE, 2014, pp. 108–114, DOI: 10.1109/CIVTS.2014.7009485.

[11] L. Bartczuk, A. Przybyl, and P. Koprinkova-Hristova, "New Method for Non-linear Correction Modelling of Dynamic Objects with Genetic Programming," *Lecture Notes in Artificial Intelligence - ICAISC'2015*, vol. 8468, pp. 318–329, 2015, DOI: 10.1007/978-3-319-07176-3_31.

[12] K. Waledzik and J. Mandziuk, "An automatically generated evaluation function in general game playing," *IEEE Trans. Comput. Intellig. and AI in Games*, vol. 6, no. 3, pp. 258–270, 2014.

[13] M. Swiechowski and J. Mandziuk, "Self-adaptation of playing strategies in general game playing," *IEEE Trans. Comput. Intellig. and AI in Games*, vol. 6, no. 4, pp. 367–381, 2014.

[14] L. Rutkowski, M. Jaworski, L. Pietruczuk, and P. Duda, "A new method for data stream mining based on the misclassification error," *IEEE Trans. Neural Netw. Learning Syst.*, vol. 26, no. 5, pp. 1048–1059, 2015.

[15] L. Rutkowski, M. Jaworski, L. Pietruczuk, and P. Duda, "Decision trees for mining data streams based on the gaussian approximation," *IEEE Trans. Knowl. Data Eng.*, vol. 26, no. 1, pp. 108–119, 2014.

[16] M. H. Horng, "Vector quantization using the firefly algorithm for image compression," *Expert Systems with Applications*, vol. 39, no. 1, pp. 1078–1091, 2012.

[17] M. Woźniak and D. Połap, "Basic concept of cuckoo search algorithm for 2D images processing with some research results : An idea to apply cuckoo search algorithm in 2d images key-points search," in *SIGMAP 2014 - Proceedings of the 11th International Conference on Signal Processing and Multimedia Applications, Part of ICETE 2014 - 11th International Joint Conference on e-Business and Telecommunications*. 28-30 August, Vienna, Austria: SciTePress, 2014, pp. 157–164, DOI: 10.5220/0005015801570164.

[18] M. Woźniak and Z. Marszałek, "An idea to apply firefly algorithm in 2D images key-points search," *Communications in Computer and Information Science - ICIST'2014*, vol. 465, pp. 312–323, 2014, DOI: 10.1007/978-3-319-11958-8_25.

[19] M. Woźniak, D. Połap, M. Gabryel, R. K. Nowicki, C. Napoli, and E. Tramontana, "Can we preprocess 2d images using artificial bee colony?" *Lecture Notes in Artificial Intelligence - ICAISC'2015*, vol. 9119, pp. 660–671, 2015, DOI: 10.1007/978-3-319-19324-3_59.

[20] M. Woźniak, C. Napoli, E. Tramontana, G. Capizzi, G. Lo Sciuto, R. K. Nowicki, and J. T. Starczewski, "A multiscale image compressor with rbfnn and discrete wavelet decomposition," in *IEEE IJCNN 2015 - 2015 IEEE International Joint Conference on Neural Networks, Proceedings*. 12-17 July, Killarney, Ireland: IEEE, 2015, pp. 1219–1225, DOI: 10.1109/IJCNN.2015.7280461.

[21] M. H. Horng and R. J. Liou, "Multilevel minimum cross entropy threshold selection based on the firefly algorithm," *Expert Systems with Applications*, vol. 38, no. 12, pp. 14 805–14 811, 2011.

[22] A. Kavousi-Fard, H. Samet, and F. Marzbani, "A new hybrid modified firefly algorithm and support vector regression model for accurate short term load forecasting," *Expert Systems with Applications*, vol. 41, no. 13, pp. 6047–6056, 2014.

[23] A. Baykasoğlu and F. B. Ozsoydan, "An improved firefly algorithm for solving dynamic multidimensional knapsack problems," *Expert Systems with Applications*, vol. 41, no. 8, pp. 3712–3725, 2014.

[24] E. Valian, S. Tavakoli, S. Mohanna, and A. Haghi, "Improved cuckoo search for reliability optimization problems," *Computers & Industrial Engineering*, vol. 64, no. 1, pp. 459–468, 2013.

[25] M. Gabryel, M. Woźniak, and R. Damaševičius, "An application of differential evolution to positioning queueing systems," *Lecture Notes in Artificial Intelligence - ICAISC'2015*, vol. 9120, pp. 379–390, 2015, DOI: 10.1007/978-3-319-19369-4_34.

[26] M. Woźniak, D. Połap, R. K. Nowicki, C. Napoli, G. Pappalardo, and E. Tramontana, "Novel approach toward medical signals classifier," in *IEEE IJCNN 2015 - 2015 IEEE International Joint Conference on Neural Networks, Proceedings*. 12-17 July, Killarney, Ireland: IEEE, 2015, pp. 1924–1930, DOI: 10.1109/IJCNN.2015.7280556.

[27] C. Napoli, G. Pappalardo, E. Tramontana, Z. Marszałek, D. Połap, and M. Woźniak, "Simplified firefly algorithm for 2D image key-points search," in *IEEE SSCI 2014 - 2014 IEEE Symposium Series on Computational Intelligence - CIHLI 2014: 2014 IEEE Symposium on Computational Intelligence for Human-Like Intelligence, Proceedings*. 9-12 December, Orlando, Florida, USA: IEEE, 2014, pp. 118–125, DOI: 10.1109/CIHLI.2014.7013395.

[28] S. Spiro, *Lung Cancer*. Sheffield: ERS Jourals Ltd, 2001.

[29] U. S. D. of Health and Welfare, "Smoking and health: Report of the advisory committee to the surgeon general of the public health service," 1964.

[30] S. Hecht, "Tobacco carcinogens, their biomarkers and tobacco-induced cancer," *Nature Reviews Cancer*, vol. 3, no. 10, pp. 733–744, 2003.

[31] T. Perfetti and A. Rodgman, "The complexity of tobacco and tobacco smoke," *Beiträge zur Tabakforschung International*, vol. 24, no. 5, pp. 215–232, 2014.

[32] M. Goniewicz, B. Koszowski, C. J., T. Kuma, M. Gawron, L. Kośmider, J. Knysak, and A. Sobczak, "Variations in nicotine yields between single cigarettes," *Central European Journal of Public Health*, vol. 20, no. 1, pp. 58–61, 2012.

[33] M. Goniewicz, T. Kuma, M. Gawron, J. Knysak, and L. Kośmider, "Nicotine levels in electronic cigarettes," *Nicotine and Tobacco Research*, vol. 15, no. 1, pp. 158–166, 2013.

[34] M. Goniewicz, J. Knysak, M. Gawron, L. Kośmider, A. Sobczak, J. Kurek, M. Jabłońska-Czapla, C. Roski-Dulewska, C. Havel, P. Jacob, and N. Benowitz, "Levels of selected carcinogens and toxicants in vapour from electronic cigarettes," *Tobacco Control*, vol. 23, no. 2, pp. 133–139, 2014.

[35] M. Infante and J. Pedersen, "Screening for lung cancer: are we there yet?" *Current Opinion in Pulmonary Medicine*, vol. 16, no. 4, pp. 301–306, 2010.

[36] P. Azad, T. Asfour, and R. Dillmann, "Combining harris interest points and the sift descriptor for fast scale-invariant object recognition," in *IROS'2009 Proceedings*. IEEE, 2009, pp. 4275 – 4280.

[37] P. Decker and D. Paulus, "Model based pose estimation using surf," in *ACCV'2010 - Lecture Notes in Computer Science*, no. 6469. Springer, 2011, pp. 11–20.

[38] G. Lowe, "Distinctive image features from scale-invariant keypoints," *International Journal of Computer Vision*, vol. 60, no. 2, pp. 91–110, 2004.

[39] G. Capizzi, C. Napoli, and F. Bonanno, "Innovative second-generation wavelets construction with recurrent neural networks for solar radiation forecasting," *IEEE Transactions on Neural Networks and Learning Systems*, vol. 23, no. 11, pp. 1805–1815, 2012.

[40] J. Graham, J. Starzyk, and D. Jachyra. Opportunistic behavior in motivated learning agents. *IEEE Trans. Neural Netw. Learning Syst.*, 26(8):1735–1746, 2015. DOI: 10.1109/TNNLS.2014.2354400.

[41] A. Horzyk. How does generalization and creativity come into being in neural associative systems and how does it form human-like knowledge? *Neurocomputing*, 144:238–257, 2014. DOI: 10.1016/j.neucom.2014.04.046.

[42] C. Napoli, G. Pappalardo, and E. Tramontana, "A hybrid neuro-wavelet predictor for qos control and stability," *Lecture Notes in Artificial Intelligence - AI*IA 2013*, vol. 8249, pp. 527–538, 2013.

[43] A. Niewiadomski, "On Finity, Countability, Cardinalities, And Cylindric Extensions of Type-2 Fuzzy Sets in Linguistic Summarization of Databases," *IEEE Transactions on Fuzzy Systems*, vol. 18, no. 3, pp. 532–545, 2010.

[44] A. Niewiadomski, "A Type-2 Fuzzy Approach to Linguistic Summarization of Data," *IEEE Transactions on Fuzzy Systems*, vol. 16, no. 1, pp. 198–212, 2008.