Classifier for Confocal Thyroid Imaging on Single Board Computers

1st Konstantin Kurochka
Sukhoi State Technical University of Gomel
Gomel, Belarus
kurochka@gstu.by

2nd Alexander Demidov
Sukhoi State Technical University of Gomel
Gomel, Belarus
demidovmainmailbox@gmail.com

***Abstract*—The paper proposes the architecture of a convolutional neural network for classification of digital images of the thyroid gland obtained using a laser confocal microscope. The possibility of using single-board computers as a basis for building a full-fledged device for classifying images with high mobility and versatility is being considered. The process of preparing data for training and comparing existing single-board computers available.**

I. Introduction

Recently, interest in building mobile energy-efficient and resource-intensive system, with using micro-platforms has increased in many areas of industry, and medicine is no exception. This area has always been at the forefront of technology, while the capabilities of personal computers were relatively small, and distributed systems [1] were used to process digital images in view of the required capacities.

However, the development of technology has allowed the same amount of calculations, but on more compact devices.

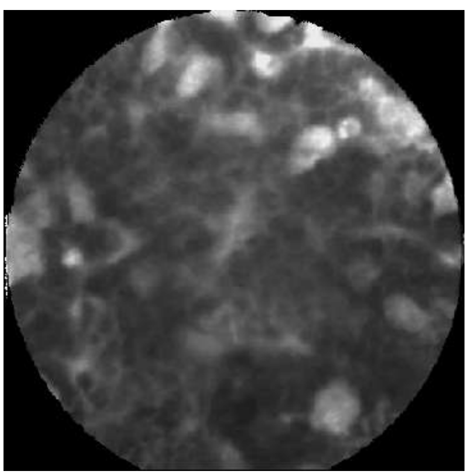

Figure 1. An example of a confocal image of the thyroid gland with a pronounced adenoma.

The development of machine learning has enabled the use of neural networks to recognize and localize objects in medical images [2] [3]. One of these areas has become microscopy. Data from various electron microscopes should be analyzed quickly enough to establish a diagnosis. One such data source can be considered a confocal laser microscope. Confocal microscopy helps microbiologists solve a number of specific problems.

This method is used to study the structure of cells, their nucleus and mitochondria, chromosomes and genes. With its help, one can observe many dynamic processes: features of cellular transport of various compounds, redistribution of ions within a living cell. Confocal microscopy helps to model three-dimensional images. Using photos of optical sections recorded in the computer's memory, you can recreate any object in maximum detail.

On the fig. 1 shows the image of the thyroid gland during surgery obtained using a confocal laser microscope. Due to the fact that the microscope is a closed device, the introduction of new functionality is impossible or is an extremely rare and expensive procedure.

It is proposed to use a convolutional neural network and a third-party device based on a single-board computer to classify modified tissues using confocal images of the thyroid gland. This approach will minimize the cost of adding new features to a confocal microscope.

This solution will also significantly speed up the time and number of patients under consideration due to the fact that ordinary cases with a pronounced presence or absence of thyroid modifications will be detected automatically, this will allow patients to be sorted for various types of tests or various techniques. It should be noted right away that when using single-board computers and placing a neural network on them, the problem of limited resource capabilities of devices arises.

The selection conditions for testing devices were their technical characteristics, price and availability of platforms on the Belarusian market. A comparative analysis of single-circuit devices in solving classification problems using the proposed convolutional neural network is carried out. The corresponding software was developed using tools in the Python language and the operating systems Armbian and Ubuntu, adapted for use on single-board computers with limited resources.

II. Convolutional Network Classifier

When analyzing data obtained from a confocal microscope, two main parameters are important - this is the quality and speed of the network. In the course of solving the problem of classification of images of the thyroid gland, a comparative analysis of various devices for the implementation of the image classifier was carried out.

The solution to the problem of recognition of confocal images of the thyroid gland consists of several stages:

- Building a network model.
- Data preprocessing.
- Network quality training and validation.

The training data-set consists of 250 images of expressed thyroid adenoma, 250 images of a expressed normal state and 400 images of boundaries and poorly defined areas. Based on the limited sampling, it was decided to artificially increase the dimension of the data-set. For this, the following operations were carried out:

- Collection of graphic data. Getting confocal images
- Filtering - checking images for a number of requirements: a sufficient level of illumination of objects on them, the presence of the necessary object. All noisy and low-quality images were used to create a negative class.
- Preparation of tools for marking. Selection of the necessary image generation algorithms.
- Create new images. Apply filters and distortion.

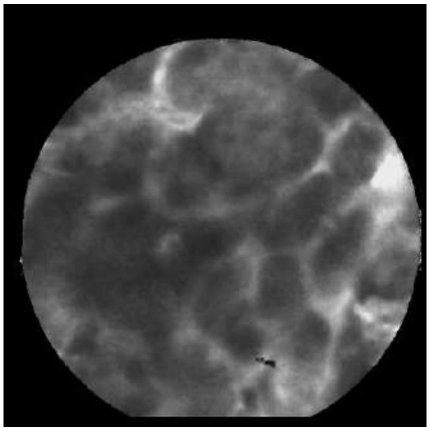

Figure 2. An example of a confocal image of a healthy thyroid gland.

After carrying out these operations, the dimension of the data-set was increased by 1.5 times. This will increase the flexibility of the network in solving the problem. The data-set was artificially expanded due to augmentation of data to 1350. The source data is divided in the proportions of 75% of educational to 25% of validation. On the fig. 2 illustrates confocal images of healthy thyroid.

Neural network written in high level Python using TensorFlow machine learning library [4] and with framework Keras [5]. On the fig. 3 illustrates the network architecture that was used in training the network.

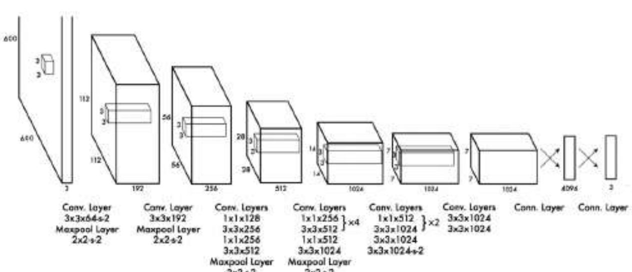

Figure 3. Model of neural network.

The network consists of convolutional and fully connected layers. The first convolutional layer contains 128 convolution cores 3 * 3, after each convolutional layer there is an activation layer ReLU:

$$f(x) = max(0, x) \tag{1}$$

Several fully connected layers follow convolutional layers; the last layer contains the Softmax function. Adam was used as an optimization function.

A three-channel image with a size of 600px * 600px is fed to the network input, after which the data passes through a set of convolutional and ReLU layers, which transmit a set of features to fully connected layers. The output of the network is a vector of dimension equal to the number of classes of objects.

To train the network, a personal computer with a video card was used NVIDIA GTX 1080TI. On the fig. 4 and 5 shows the results of the quality of accuracy after training the network in 50 epoch, for the training samples is 83% and 79% for the validating samples.

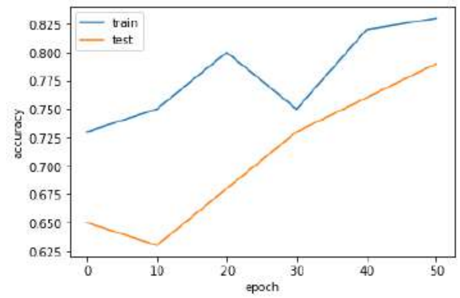

Figure 4. Model accuracy.

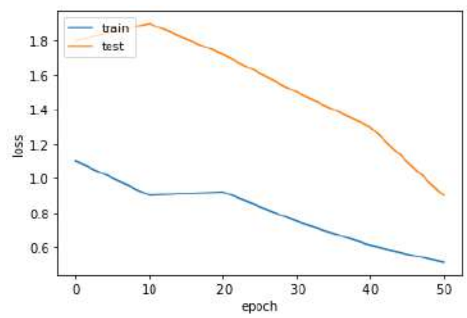

Figure 5. Model loss.

Testing was conducted under the control of the Armbian 4.19 operating system, the following software was used: Python version 3.5.4, version Keras and TensorFlow 2.2.3 and 1.12, respectively.

III. Single Board Computer Test

The following single-board computers were used in this test

- Banana PI M1.
- Orange PI One.
- Khadas VIM.
- Asus Tinker Board.

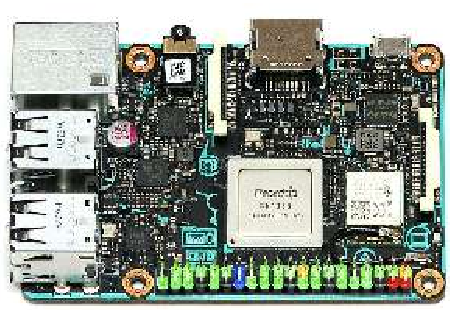

Figure 6. Example of Single Board Computer.

The Banana Pi BPI-M1 and Orange PI One are a business card-sized and low-power single-board computers. They are an open platform devices, that provide possibility for community build decision. Khadas VIM is more powerfully then previous two sample and it is actually a TV box. Khadas Vim is completely open source and all the resources available on GitHub too. Asus Tinker Board is a SBC in an ultra-small form factor that offers class-leading performance while leveraging outstanding mechanical compatibility. The Tinker Board offers makers, IoT enthusiasts, hobbyists, PC DIY enthusiasts and others a reliable and extremely capable platform for building and tinkering their ideas into reality. Prices for devices range from 23$ to 100$ and directly affect the level of their capabilities.

Table I
SINGLE BOARD COMPUTER PROPERTIES

Feature list	Devices under consideration	
	Banana PI M1 [6]	*Orange PI One [7]*
Release date	09.02.2015	29.01.2016
Price	25	23
Length Width	92 mm 60 mm	69 48
CPU	A20	H3
Frequency	1GHz	1.2GHz
Number of Cores	2	4
RAM	1 Gb	512 Mb
GPU	Mali-400 MP2	Mali400 MP2

As follows from the considered characteristics of the devices, the main and most productive solutions are Khadas VIM and Asus Tinker Board, these models can even handle 4K video playback, in addition, these devices have a built-in WI-FI and Bluetooth. It should be noted that all solutions offer an almost identical set of input / output devices, all devices can be connected to an Ethernet network, and also have from 2 to 4 USB ports, there is also a universal input / output interface (GPIO), through this interface you can listen and give commands to any external device, this interface significantly increases the area of use of single-board computers.

Table II
SINGLE BOARD COMPUTER PROPERTIES

Feature list	Devices under consideration	
	Khadas VIM [8]	*Tinker Board [9]*
Release date	12.06.2017	04.04.2017
Price	69	60
Length Width	82 mm 57 mm	79 mm 60 mm
CPU	Amlogic S905X	Rockchip RK3288
Frequency	1.5GHz	1.8GHz
Number of Cores	4	4
RAM	2	2
GPU	Mali-T450MP5	Mali-T764

IV. DEVICE TESTING

After a series of experiments with the corresponding devices, a graph was compiled containing the results of the recognition quality, as well as data on the cost of the device on which the recognition was carried out. ASUS Tinker Board shows the highest speed, beating competitors by 33%. If we consider only the lower segment of solutions, then here is the advantage for Orange PI One.

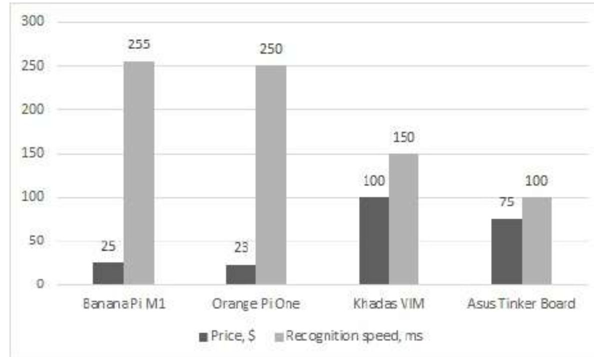

Figure 7. The result of testing the speed of the neural network on the devices.

As a result of testing, the following strengths and weaknesses of these devices can be distinguished.

Banana PI M1

This device is cheaper than all submitted samples, which allows its use in solutions with a limited budget. It has one of the largest communities because, it is used by many enthusiasts to create systems. But the device relatively few additional sources of input / output data, which creates certain problems when connecting a large number of peripheral devices. Have problem with weak equipment for graphical interface.

Orange PI One

The device have a large number of different operating systems, supports various builds of Linux and Android. As well as the previous example, there are relatively few additional sources of input / output data, which creates certain problems when connecting a large number of peripheral devices.

Khadas VIM

Khadas is have a built-in Wi-Fi module, which significantly increases the mobility of the device. High-performance equipment capable of playing 4K video. The presence of built-in flash memory. Main weak is quite a small community around this device, due to the low popularity of this device.

Asus Tinker Board

This device have a large number of I/O sources allows to connect a large number of peripheral devices to it. Availability of complete radiators for additional heat removal from the main elements of the board. High overall performance solutions in many tasks, suitable for use in systems with a graphical interface. wide range of operating systems for this platform, from Linux and Android builds to custom solutions - TinkerOS. It have high heat transfer, which requires additional solutions from the heat sink system.

The paper reviewed the neural network architecture for binary classification of digital images of the thyroid gland. The results of a comparative analysis of four single-board computers in image recognition suggest that the Asus Tinker Board model is most suitable for solving the problem of confocal image recognition. This model has the best rate of image recognition, a sufficient number of additional input / output sources, as well as optimal dimensions.

V. Conclusion

In this work, algorithm for constructing a classifier for images of the thyroid gland obtained using confocal microscopy were developed and tested. A comparative analysis of the speed of the developed classifier using several representatives of SBC.

The results of a comparative analysis of five single-board computers allow us to conclude that the Asus Tinker Board model is the most productive model and is suitable for solving the problem of confocal image recognition. This model has the best indicator of image recognition speed, a sufficient number of additional input / output sources, but it is worth noting that this solution is the most expensive. If review each device, can highlight the main features of these solutions: relatively low cost, which allows the use of devices to create home systems or prototypes of more complex solutions; the size of these devices practically does not exceed the size of a plastic card; device performance is sufficient for use as a small server; relatively poorly developed information input / output capabilities, in addition to the hosted GPIO interface, impose some inconvenience when working with them, since not every device has a built-in Wi-Fi or Bluetooth module.

It should be noted that currently there are many devices for various needs, from basic solutions for home use to modern hardware acceleration systems for the operation of trained models of neural networks [10]. Therefore, when developing various systems, an analysis of devices on the market is required. to find the best price / performance ratio. According to the results of testing a model of our own design on a test sample of 14 images, the accuracy of the network can be 83%.

Acknowledgment

The authors are grateful to all those who simply do not intervene.

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Классификатор конфокальных изображений щитовидной железы на одноплатных компьютерах

Курочка К.С., Демидов А.И.

В статье рассматривается архитектура сверточной нейронной сети для классификации цифровых изображений щитовидной железы, полученных с помощью лазерного конфокального микроскопа. Предлагается способ увеличения возможностей использования лазерного конфокального микроскопа с помощью одноплатных компьютеров для классификации модифицированных тканей. Разработано соответствующее программное обеспечение, адаптированное для использования на одноплатных компьютерах, с ограниченными ресурсными возможностями. Проведен сравнительный анализ одноплатных устройств при решении задач бинарной классификации с использованием рассмотренной сверточной нейронной сети. Факторами отбора устройст для испытаний были выделены их технические характеристики, невысокая цена и доступность платформы на рынке Беларуси. Описаны сильные и слабые стороны при использовании данных устройств. Кратко приведены их характеристики. Предполагается, что приведенные устройства или их аналоги могут быть использованы для построения мобильных и энергоемких систем обработки информации при ограниченных возможностях, как пример обработка конфокальных изображений щитовидной железы.

Received 15.01.2020