Efficient Classification Of Brain Tumors Images Using Neural Network Technique

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Abstract

Using biopsy, brain tumor classification is performed, which is not normally conducted before definitive brain surgery. Technology improvement and machine learning help radiologists with the diagnostics of tumors without invasive measures. Convolutional neural network (CNN) is the machine-learning algorithm that achieved substantial results in image classification and segmentation. Some of the most notable primary brain tumors are meningiomas, gliomas, and pituitary tumors. Gliomas is a general term for a tumor that arises from brain tissues other than nerve cells and blood vessels. But, meningiomas arise from membranes that cover the brain and surround the central nervous system, whereas pituitary tumors are the lumps that sit inside the skull. The most notable important difference between these three types is that meningiomas are generally benign, and gliomas are commonly malignant. This project develops a new CNN architecture to classify brain tumor types. With i) good generalization capability and ii) good execution speed, the newly developed CNN architecture is being used as an effective decision-support tool for radiologists in diagnostics. Python is used for the development of the project.

Keywords: Deep Learning, Neural Network, Brain Tumor, MRI Images.

I. INTRODUCTION

Cancer is the second leading cause of death worldwide, according to the World Health Organization (WHO) [1]. Early detection of it can prevent death, but this is not possible all time. Unlike cancer, the tumor also could be benign, malignant, or pre-carcinoma. Benign tumors vary from malign in that, benign normally don't spread to other organs and tissues and are surgically removed [2]. Some brain tumors are meningiomas, gliomas, and pituitary tumors. Gliomas are a general term for tumors that arise from brain tissues other than nerve cells and blood vessels. But, meningiomas arise from the membranes that cover the brain and surround the central nervous system, but pituitary tumors are the lumps that sit inside the skull [3 –6]. The primary difference between these three types is that meningiomas are benign, and gliomas are commonly malignant. Pituitary tumors, even if benign, cause other medical damage, not similar to meningiomas, which are slow-growing tumors [5, 6]. Because of the information mentioned above, precise differentiation between the three types of tumors denotes a very important step of the clinical diagnostic process and later the patient's effective assessment.

The most common method to differentially diagnose tumor type is the magnetic resonance imaging (MRI) method. But it is prone to human subjectivity, and a large amount of data is difficult to observe for humans. Also, old brain–tumor detection mostly depends upon the experience of radiologists [7]. The diagnostics of a tumor can not be complete before establishing if it is benign or malignant. To examine if the tissue is benign or malignant, a performance of biopsy is usually required. Unlike tumors elsewhere in the body, a biopsy of a brain tumor is not usually obtained before the definitive brain surgery [8]. To get precise diagnostics, and eliminate surgery and subjectivity, it is a must to consider an effective diagnostics tool to segment and classify tumors from MRI images [7].

The development of new technologies, especially AI and ML, has had a significant impact on the medical field, thus providing an important support technology for many medical branches, which includes imaging. Various machine-learning methods to segment and classify images are applied in MRI image processing for providing radiologists with a second opinion. Since 2012, the Perelman School of Medicine at the University of Pennsylvania, Center for Biomedical Image Computing and Analytics (CBICA) is running an online competition, Multimodal Brain Tumor Segmentation Challenge (BRATS) [9]. Image databases utilized in BRATS are made available publicly after the competition is finished. Various classification algorithms designed using these databases are found in many papers [10– 14]. Still, these databases are usually small, on average about 284 images, and often contain images that show two tumor levels, low and high-level glioma tumors, acquired in the axial plane [10]. Moreover, classification is carried out on the other image databases, which are also quite small [15 to 18]. Mohsen with his team used 65 images for classifying four types of images that show brain tumors: a) tumor-free, b) glioblastoma, c) sarcoma, and d) metastasis. By using Deep Neural Network (DNN), the authors obtained an accuracy of 96.95% [17]. There are other algorithms and various modifications of pre-trained networks that are commonly used for image classification, analysis, and segmentation. Various approaches are tested on other medical databases also, both on MRI images of brain tumors as well as on tumors from different parts of the human body [19, 20]. These papers were not further considered, as their focus was on the papers using the same MRI image database that they used.

Cheng with tema who were the first to show image database used in that paper, classified those tumor types by using tumor region augmentation of interest, ring-form partition and image dilatation. They extracted features by using intensity histogram, bag-of-words models, and gray level co-occurrence matrix and achieved an accuracy of 91.27% [21]. Different types of networks there, pre-trained ones, other architectures of convolutional networks, capsule net networks, and combinations with neural networks to extract features and classifiers for output result are discussed. The discussion also have approaches using various modifications of database, as well as the original one. The papers that used original or augmented database are listed in tables to compare better. The biggest problem in classifying and segmenting MRI images (using some neural networks) is in the images count in database. Moreover, MRI images might be acquired in various planes, so the option of using the entire available planes can enlarge that database.

As this could affect the classification output by overfitting generally, the requirement of pre-processing before feeding images into the neural network is necessary. But, one of the known advantages of CNN is that pre-processing and feature engineering need not be performed.

The aim of the authors was firstly to examine classification of three tumor types from an imbalanced database with CNN.

Even though, they considered large compared to another available MRI image databases, the database is still far smaller than other databases generally used in field of artificial intelligence. It is true that the performance of small architecture could compare favorably with performance of the more complex ones too.

Using a small network requires miminum resources to train and implement. This is one of the most crucial problems for addressing because few available resources make it is difficult to utilize the system in clinical diagnostics and also in mobile platforms. If the system is required to be used in day-to-day clinical diagnostics, it must be generally applicable. Network's generalization capability to study clinical should be examined. The rest of this paper is organized as follows: Section 2 reviews the existing security approaches under recent studies and explains previous works and their drawbacks. Section 3 provides proposed methodology. Section includes the findings. Section 5 is the conclusion of the study.

II. LITERATURE REVIEW

In the paper (1] WORLD HEALTH ORGANIZATION GLOBAL bandied about the crucial data of cancer. They are

• Cancer is a leading cause of death worldwide, counting for nearly 10 million deaths in 2020, or nearly one in six deaths.

• The most common cancers are bone, lung, colon and rectum and prostate cancers.

• Around one-third of deaths from cancer are due to tobacco use, high body mass indicator, alcohol consumption, low fruit and vegetable input, and lack of physical exertion.

• Cancer-causing infections, similar as mortal papillomavirus (HPV) and hepatitis, are responsible for roughly 30 of cancer cases in low-and lower- middle-income countries.

• Numerous cancers can be cured if detected beforehand and treated effectively.

Cancer is a general term for a large group of conditions that can affect any part of the body. Other terms used are nasty tumours and tumors. One defining point of cancer is the rapid-fire creation of abnormal cells that grow beyond their usual boundaries, and which can also foray touching corridor of the body and spread to other organs; the ultimate process is appertained to as metastasis. Wide metastases are the primary cause of death from cancer.

The problem

Cancer is a leading cause of death worldwide, counting for nearly 10 million deaths in 2020. The most common in 2020 (in terms of new cases of cancer) were

• bone (2.26 million cases);

• lung (2.21 million cases);

• colon and rectum (1.93 million cases);

• prostate (1.41 million cases);

• skin (non-melanoma) (1.20 million cases); and

• stomach (1.09 million cases).

The most common causes of cancer death in 2020 were

• lung (1.80 million deaths);

• colon and rectum (916 000 deaths);

• liver (830 000 deaths);

• stomach (769 000 deaths); and

• bone (685 000 deaths).

Each time, roughly 400 000 children develop cancer. The most common cancers vary between countries. Cervical cancer is the most common in 23 countries.

What causes cancer?

Cancer arises from the metamorphosis of normal cells into tumour cells in amulti-stage process that generally progresses from apre-cancerous lesion to a nasty tumour. These changes are the result of the commerce between a person's inheritable factors and three orders of external agents, including

- physical carcinogens, similar as ultraviolet and ionizing radiation;
- chemical carcinogens, similar as asbestos, factors of tobacco bank, alcohol, aflatoxin (a food adulterant), and arsenic (a drinking water adulterant); and
- natural carcinogens, similar as infections from certain contagions, bacteria, or spongers.

WHO, through its cancer exploration agency, the International Agency for Research on Cancer (IARC), maintains a bracket of cancer-causing agents. The prevalence of cancer rises dramatically with age, most probably due to a figure-up of pitfalls for specific cancers that increase with age. The overall threat accumulation is combined with the tendency for cellular form mechanisms to be less effective as a person grows aged.

Threat factors for cancers

Tobacco use, alcohol consumption, unhealthy diet, physical inactivity and air pollution are threat factors for cancer and other noninfectious conditions. Some habitual infections are threat factors for cancer; this is a particular issue in low-and middle- income countries. Roughly 13 of cancers diagnosed in 2018 encyclopedically were attributed to carcinogenic infections, including Helicobacter pylori, mortal papillomavirus (HPV), hepatitis B contagion, hepatitis C contagion, and Epstein-Barr contagion. Hepatitis B and C contagions and some types of HPV increase the threat for liver and cervical cancer, independently.

Infection with HIV increases the threat of developing cervical cancersix-fold and mainly increases the threat of developing select other cancers similar as Kaposi sarcoma.

Reducing the cancer burden

Between 30 and 50 of cancers can presently be averted by avoiding threat factors and enforcing being substantiation- grounded forestallment strategies. The cancer burden can also be reduced through early discovery of cancer and applicable treatment and care of cases who develop cancer. Numerous cancers have a high chance of cure if diagnosed beforehand and treated meetly.

Precluding cancer

Cancer threat is reduced by

• not consuming tobacco and maintaining a healthy body weight;

• having a healthy diet, including fruit and vegetables and doing physical exertion on a regular base;

• avoiding /reducing alcohol consumption and getting vaccination against HPV and hepatitis B if you belong to a group for which vaccination is recommended;

• avoid ultraviolet radiation exposures (that primarily results from exposure to the sun and artificial tanning bias) and / or using sun/heat protection measures and icing safe and applicable use of radiation in health care (for individual and remedial purposes);

• to minimize occupational exposure to ionizing radiation; and reduce exposure to out-of-door air pollution and inner air pollution, includes radon (a radioactive gas produced from natural decay of uranium, which accumulate in structures — seminaries,homes and workplaces).

Beforehand discovery

Cancer death is reduced when cases detected and treated beforehand. There are some factors of early discovery i.e., early opinion and webbing.

Early opinion

When linked , cancer is likely to respond to treatments and affect in lesser probability of survival with lower morbidity, and less precious treatment. Significant advancements are made in lives of cancer cases through detecting cancer beforehand as well as avoiding detainments in care.

Early opinion consists of three factors

• being apprehensive for symptoms of different cancer forms and significance of seeking medical advice when abnormal findings are found;

• accessing to clinical evaluation and individual services; and

• timely referring to treatment services.

Early opinion of characteristic cancers are applicable in the entire settings and maturity of cancers.

Cancer programmes are designed to reduce detainments in, and walls to, treatment,opinion and probative care.

Webbing

It aims for identifying individualities with finding suggestive for a specific cancer orpre-cancer before they have developed symptoms. When abnormalities could be linked during webbing, farther tests for establishing a definitive opinion must follow, as shall referral for treatment if cancers are proven to be present

Webbing programmes are effective for some types but not all cancer types; in general they are far more complex, resource-ferocious than early opinion as they bear special outfit, devoted help. When screening programmes are established, early opinion programmes are necessary for identifying those cancer cases in people who do not meet age or threat factor criteria for webbing.

Webbing programme case selection is grounded on age and threat factors for avoiding inordinate false positive studies.

Exemplifications of webbing styles are

• HPV tests (HPV DNA and mRNA test), as modality for cervical cancer webbing; and

• mammography webbing to bone cancer for women of age category 50 – 69 abiding in settings which include strong or fairly strong health systems.

Quality assurance is needed in both webbing as wel as early opinion programmes.

Treatment

The correct cancer opinion is must for applicable, effective treatment since every cancer type needs a specific treatment authority. Treatment normally includes radiotherapy, surgery, and/ or chemotherapy, hormonal treatments and targeted natural curatives.

Prooper selection of the treatment authority required so both cancer and existent being treated. Completion of treatment protocol in the defined time period is must to yield the prognosticated remedial result.

Determining the treatment pretensions is the first step. The primary thing is normally for curing cancer or for vastly protracting life. Perfecting the case's quality of life is also an important thing. This can be achieved by support for the case’s physical, psychosocial and spiritual well- being and palliative care in cancer terminal stages. Some of the common cancer types, equal to cervical cancer, bone cancer, oral cancer, and colorectal cancer, are having high cure chances when detected and treated according to new practices.

Some other cancer types, similar as testicular seminoma, different types of leukaemia / carcinoma in children, also having high cure rates if applicable treatment is being handed, indeed where cancerous cells are present in other areas of body.

There is, a significant variation in treatment vacuity among countries of different income situations; comprehensive treatments are reportedly there in further than 80 of high-income countries but lower than 15 of medium as well as low income countries.

Palliative care

Palliative care is treatment to relieve, rather than cure, symptoms and suffering caused by cancer and to improve the quality of life of patients and their families. Palliative care can help people live more comfortably. It is particularly needed in places with a high proportion of patients in advanced stages of cancer where there is little chance of cure. Relief from physical, psychosocial, and spiritual problems through palliative care is possible for more than 90% of patients with advanced stages of cancer. Effective public health strategies, comprising community- and home-based care, are essential to provide pain relief and palliative care for patients and their families. Improved access to oral morphine is strongly recommended for the treatment of moderate to severe cancer pain, suffered by over 80% of people with cancer in the terminal phase.

In the paper [2] cancer treatments centers of america—brain cancer types, the author discussed cancer types.

Brain cancer types

In this paper [2] the author approved that brain tumors have more than 120 different types, according to the National Brain Tumor Society. Some brain tumors, such as a glioblastoma multiforme, are malignant and may be fast-growing. Other types of brain tumors, such as a meningioma, may be slow-growing and benign. Primary brain tumors form in brain cells and are categorized by the type of cell or where in the brain they first develop. For instance, astrocytomas form in star-shaped cells called astrocytes. Pituitary tumors are found in the pituitary gland at the bottom of the brain. The most common primary brain tumors are called gliomas, which originate in the glial (supportive) tissue.

About one-third of all primary brain tumors and other nervous system tumors form from glial cells. Aside from tumors in the brain, cancer may begin in, or spread to, other areas of the central nervous system (CNS), such as the spinal cord or column, or the peripheral nerves. Cancer that develops in the spinal cord or its surrounding structures is called spinal cancer. Most tumors of the spine are metastatic tumors, which have spread to the spine from another location in the body.

Are brain tumors cancerous?

Many brain tumors are cancerous. For example, more than half of all gliomas diagnosed in adults are glioblastomas, a very aggressive form of brain cancer. Ependymomas and oligodendrogliomas also are types of brain tumors that may be malignant. But not all brain tumors are cancerous. Many meningiomas, **craniopharyngiomas** and pituitary tumors are benign. That's why it's important to get a thorough and accurate diagnosis of a brain tumor.

It's also important to understand that even benign tumors can damage brain tissue and cause side effects, such as headaches, fatigue and double or blurred vision. So even if a brain tumor is not cancerous, receiving timely and appropriate treatment may be critical to your overall health.

Types of brain cancer

Astrocytomas, which are the most common CNS tumor, arise anywhere in the brain or spinal cord, and develop from small, star-shaped cells called astrocytes. In adults, astrocytomas most often occur in the cerebrum, the largest part of the brain. The cerebrum uses sensory information to tell us what's going on around us and how the body should respond. The cerebrum also controls speech, movement and emotions, as well as reading, thinking and learning. Brain stem gliomas are a type of astrocytoma that forms in the brain stem, which controls many vital functions, such as body temperature, blood pressure, breathing, hunger and thirst. The brain stem also transmits all the signals to the body from the brain. The brain stem is in the lowest part of the brain and connects the brain and spinal cord. Tumors in this area can be difficult to treat. Most brain stem gliomas are high-grade astrocytomas.

Glioblastoma multiforme, also known as glioblastoma, GBM or grade 4 astrocytoma, is a fast-growing, aggressive type of CNS tumor that forms on the supportive tissue of the brain. Glioblastoma is the most common grade 4 brain cancer. Glioblastomas may appear in any lobe of the brain, but they develop more commonly in the frontal and temporal lobes. Glioblastomas usually affect adults.

Meningioma develop in the cells of the membrane that surround the brain and spinal cord. Meningiomas (also called meningeal tumors) account for approximately 15 percent of all intracranial tumors. Most of these tumors are benign (non-cancerous and slow-growing). Meningiomas are typically removed with surgery. Some meningiomas may not need immediate treatment and may remain undetected for years. Most meningiomas are diagnozed in women between 30 and 50 years old. Aside from astrocytomas, there are a number of different primary brain tumors and other nervous system tumors that form from glial cells. They include:

- Ependymomas, which usually occur in the lining of the ventricles, or spaces in the brain and around the spinal cord. Although ependymomas may develop at any age, these brain cancer tumors are most common in children and adolescents. Ependymomas are also a common spinal cord tumor.
- Oligodendrogliomas develop in the cells that produce myelin, the fatty covering that protects nerves in the brain and spinal cord. These tumors are very rare, and usually occur in the cerebrum. They are slow-growing and generally do not spread into surrounding brain tissue. These brain tumors occur most often in middle-aged adults. They generally have more favorable outcomes than astrocytomas.
- Mixed gliomas have two types of tumor cells: oligodendrocytes and astrocytes. This type of brain tumor most often forms in the cerebrum..

Pituitary tumors

Pituitary tumors are lumps that form in the pituitary, a small gland about the size of a pea that sits inside the skull, just below the brain and above the nasal passages. The pituitary gland produces hormones that control the levels of other hormones secreted by endocrine glands throughout the body, giving it an important role in controlling key body functions and the hormonal system.

The pituitary gland is made up of four parts: the anterior (front) lobe and posterior (back) lobe, which function independently of each other, as well as the intermediate area between the two lobes and the stalk that connects the pituitary to the interbrain (which includes the thalamus, hypothalamus and epithalamus). Most pituitary tumors form in the anterior lobe. They very rarely develop in the posterior lobe. Pituitary tumors represent 9 to 12 percent of all primary brain tumors. The vast majority of pituitary tumors are pituitary adenomas, benign growths that do not spread beyond the skull. Even though these tumors are not cancerous, they often cause other medical issues because they are located near the brain and may cause the pituitary to produce excess hormones.

Pituitary cancers, called pituitary carcinomas, are very rare—only a few hundred have been documented in the United States, according to the American Cancer Society. Because pituitary cancers and benign adenomas look very similar under a microscope, the carcinomas are often diagnosed only when they spread to other parts of the body.

Other brain tumors

There are a number of different brain tumors that do not begin in glial tissue.

Craniopharyngiomas develop in the area of the brain near the pituitary gland (the main endocrine gland that produces hormones that control other glands and many body functions, especially growth) near the hypothalamus. These brain tumors are usually benign. However, they may sometimes be considered malignant because they may create pressure on, or damage, the hypothalamus and affect vital functions (such as body temperature, hunger and thirst). These tumors occur most often in children and adolescents, or adults over age 50.

Germ cell tumors arise from developing sex (egg or sperm) cells, also known as germ cells. The most common type of germ cell tumor in the brain is the germinoma. Aside from the brain, germinomas can form in the ovaries, testicles, chest and abdomen. Most germ cell tumors occur in children.

Pineal region tumors occur in or around the pineal gland, a small organ located in the center of the brain. The pineal gland produces melatonin, a hormone that plays an important role in the sleep-wake cycle. These brain cancer tumors can be slow growing (pineocytoma) or fast growing (pineoblastoma). Since the pineal region is very difficult to reach, it requires a high level of surgical expertise to remove these tumors.

Medulloblastomas are fast-growing brain tumors that develop from the neurons of the cerebellum. The cerebellum is the lower back of the brain and controls movement, balance and posture. These tumors are usually found in children or young adults.

Primary CNS lymphomas develop in lymph tissue of the brain or spinal cord. This type of brain tumor is usually found in people whose immune systems are compromised.

In the paper [3] classification of brain tumors the author "*Information has been provided by the AANS/CNS Section on Tumors"* stated that the authors stated that a listing of most of the tumors that occur in the brain or its surrounding structures is presented here. Sometimes a tumor may have more than one name. The descriptions of how the tumors behave refer to the most common patterns since there are always exceptional cases (both better and worse). Higher grade malignancies are, in general, expected to grow faster than lower grade malignancies. The comments on tumor treatment usually refer to conventional therapy (surgery, radiation and cytotoxic chemotherapy) and may not include promising new, investigational or experimental treatments. Radiosurgery may be an option for most of these tumors and its use depends upon tumor size, location and the individual patient's case. If a tumor continues to grow despite treatment, additional surgery may be recommended. This also depends on the individual patient. Clinical trials are available for many of these tumors, particularly if they are malignant or recurrent. Specific tumors are listed alphabetically in the pages to follow. Discussions of spinal cord tumors, familial syndromes and the remote effects of carcinoma follow the alphabetical listing. It should be noted that this information is provided for educational purposes only, and should not be considered to be medical advice. Questions about a specific patient should be referred to a qualified surgeon or other physician.

Lindau Syndrome

This disease (also known as von Hippel-Lindau disease) is characterized by the presence of multiple hemangioblastomas, usually in the cerebellum and the spinal cord, as well as tumors of the retina, pancreas and kidney. Surgery can be used to treat both the brain and spinal cord lesions, while radiosurgery has been reported to control some brain lesions. Inheritance is autosomal dominant. Information about the von Hippel-Lindau Family Alliance can be viewed at www.vhl.org .

Tuberous Sclerosis

This syndrome often presents in childhood and is characterized by seizures, mental retardation, specific facial lesions (hamartomas) and areas of skin discoloration. Tumors of the lining of the ventricles (subependymal giant cell astrocytomas) may block flow of the cerebrospinal fluid leading to a backup of the fluid called hydrocephalus. The tumors and hydrocephalus are usually treated with surgery. Inheritance is autosomal dominant.

Remote effects of carcinoma

Some tumors produce chemicals or hormones that can directly or indirectly cause nerve cells to die or malfunction without physically contacting those nerve cells. These chemicals are carried through the blood stream to remote areas. Although these remote effects of carcinoma are rare, they can be incapacitating. Treatment usually requires effective control of the tumor producing the substances.

In this paper [7] capsule networks for brain tumor classification based on MRI images and course tumor boundaries, the authors stated that according to official statistics, cancer is considered as the second leading cause of human fatalities. Among different types of cancer, brain tumor is seen as one of the deadliest forms due to its aggressive nature, heterogeneous characteristics, and low relative survival rate. Determining the type of brain tumor has significant impact on the treatment choice and patient's survival. Human-centered diagnosis is typically error-prone and unreliable resulting in a recent surge of interest to automatize this process using convolutional neural networks (CNNs).

CNNs, however, fail to fully utilize spatial relations, which is particularly harmful for tumor classification, as the relation between the tumor and its surrounding tissue is a critical indicator of the tumor's type.

In their recent work, they had incorporated newly developed CapsNets to overcome this shortcoming. CapsNets are, however, highly sensitive to the miscellaneous image background. The paper addresses this gap. The main contribution is to equip CapsNet with access to the tumor surrounding tissues, without distracting it from the main target. A modified CapsNet architecture is, therefore, proposed for brain tumor classification, which takes the tumor coarse boundaries as extra inputs within its pipeline to increase the CapsNet's focus. The proposed approach noticeably outperforms its counterparts.

III. PROPOSED METHODOLOGY

This study shows the image details taken which is shown below.

There are three types of tumors: meningioma (708 images), glioma (1426 images), and pituitary tumor (930 images). All images were acquired from 233 patients in three planes: sagittal (1025 images), axial (994 images), and coronal (1045 images) plane. The examples of diﬀerent types of tumors, as well as diﬀerent planes, are shown in Figure 1. The tumors are marked with a red outline. The number of images is diﬀerent for each patient.

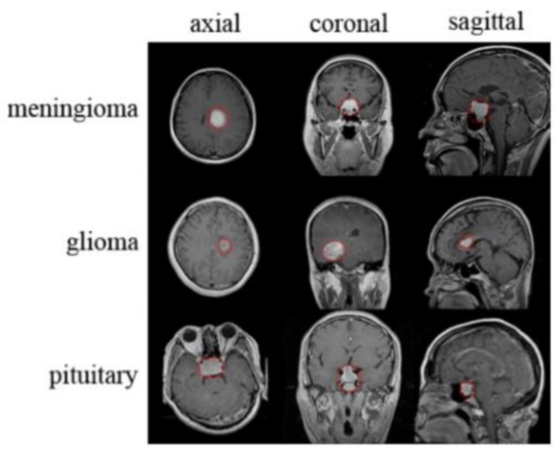

Figure 3.1. Representation of normalized magnetic resonance imaging (MRI) images showing different 115 types of tumors in different planes. In the images, the tumor is marked with a red outline. The 116 example is given for each tumor type in each of the planes.

Magnetic resonance images from the database were of different sizes and were provided in jpg format. These images represent the input layer of the network, so they were normalized and resized 120 to 256 × 256 pixels.

Tumor classification was performed using a CNN developed in Python.

The first main block, Block A, consists of a convolutional layer which as an output gives an image two times smaller than the provided input. The convolutional layer is followed by the rectified linear unit (ReLU) activation layer and the dropout layer. In this block, there is also the max pooling layer which gives an output two times smaller than the input. The second block, Block B, is diﬀerent from the first only in the convolution layer, which retains the same output size as the input size of that layer. The classification block consists of two fully connected (FC)layers,ofwhichthefirstonerepresentstheflattenedoutputo fthelastmaxpoolinglayer,whereas, in the second FC layer, the number of hidden units is equal to the number of the classes of tumor.

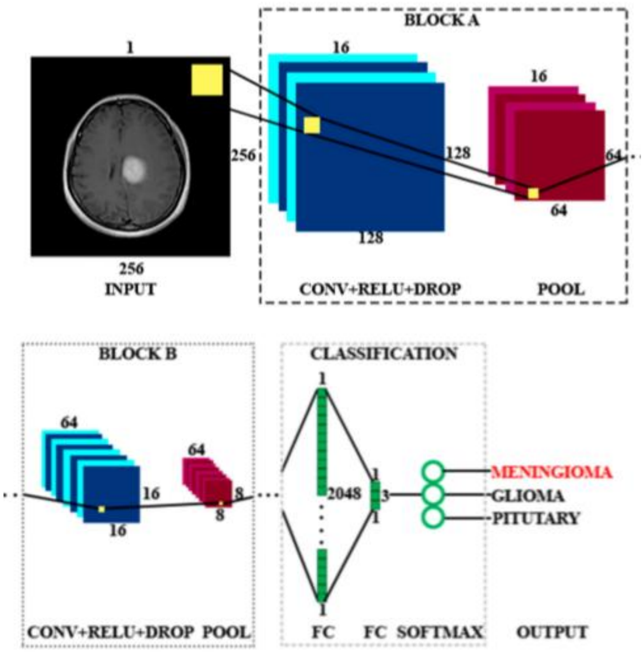

Figure 2. Schematic representation of convolutional neural network (CNN) architecture containing the input layer, two Blocks A, two Blocks B, classification block and output. Block A and Block B differ only in the convolution layer. Convolution layer in Block A gives an output two times smaller than the input, whereas the convolutional layer in Block B gives the same size output as input. The training process was stopped when the loss on the validation set got larger than or was equal to the previous lowest loss. There are several papers that use the same database for brain tumor classification. In order to compare our results with those of previous studies, we selected only those papers which had designed neural networks, used whole images as input for classification, and tested the results.

IV. FINDINGS

- The proposed architecture of the CNN obtained better results with augmented data, which was expected because the data set is not especially extensive.
- Even with the augmented data set, the subject-wise accuracy is lower than the accuracy obtained with the record-wise cross-validation because, with the augmentation, the number of images for individual patients is increased, not the number of patients.
- As a consequence of splitting the data with the subject-wise method, increasing the number of patients was more important.
- The first class of tumors, meningioma, had the lowest sensitivity and specificity for all four testing methods.

IV. CONCLUSION

A new CNN architecture for brain tumor classification was presented in this study.
The classification was performed using a T1-weighted contrast-enhanced MRI image database which contains three tumor types. As input, we used whole images, so it was not necessary to perform any preprocessing or segmentation of the tumors. Our designed neural network is simpler than pre-trained networks, and it is possible to run it on conventional modern personal computers. This is possible because the algorithm requires many less resources for both training and implementation. The importance of developing smaller networks is also linked to the possibility of deploying the algorithm on mobile platforms, which is significant for diagnostics in developing countries. In addition, the network has a very good execution speed of 15 ms per image. In order to test the network, we used record-wise and subject-wise 10-fold cross-validation on both the original and augmented image database. In clinical diagnostics, the generalization capability implies predictions for subjects from whom we have no observations. With this in mind, the observations from individuals in the training set must not appear in the test set. If this condition is not met, complex predictors can have unrealistically high prediction accuracy due to the confounding dependency between the identity and the diagnosis of a patient. A comparison with the comparable state-of-the-art methods shows that our network obtained better results. Regarding further work, other approaches to database augmentation (e.g., increasing number of subjects) in order to improve the generalization capability of the network may be studied. One of the main improvements will be adjusting the architecture so that it could be used during brain surgery, classifying and accurately locating the tumor.

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