Deep learning based-classification of dementia in magnetic resonance imaging scans

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***Abstract*-Deep learning is much preferred in image processing applications since it can give fast and important results. This research aims at developing an open source software for deep learning based-classification of dementia in magnetic resonance imaging scans. Keras (i.e., a deep-learning framework) is employed for constructing a deep learning based-model that could be discriminate between dementia patients and healthy individuals. The achieved findings demonstrate that the proposed system can be used to detect individuals with suspected dementia disease.**

***Index Terms*—Classification, deep-learning, dementia, Keras, magnetic resonance imaging.**

I. INTRODUCTION

Dementia is a condition in which mental skills are weakened by this illness. It is expected that the number of people with dementia will increase as the average life expectancy advances. The most common cause of dementia is Alzheimer's disease consisting of at least half of all dementia patients. In the world, the number of people with dementia will reach 75 million in 2030 and 131 million in 2050. In the light of these data, the presence of a system to monitor demented individuals will reduce the burden of those responsible for care [1].

Deep learning is a sub-field of artificial intelligence and employs many nonlinear processing unit layers for feature extraction, transformation and so on. Each successive layer takes the output from the previous layer as input [5]. Algorithms can be supervised (e.g., classification) or unsupervised (e.g., pattern analysis). Deep learning architectures are very important approaches for image processing, semantic video segmentation, face recognition, object detection, etc. In deep learning, there is a structure based on learning multiple levels or representations of data. Top-level properties are derived from lower-level properties to form a hierarchical representation. Deep learning is mainly based on learning from the representation of data. Representation for an image may be considered as; a vector of density values per pixel, or features such as edge clusters and custom shapes. Some of these features represent data better. As an advantage at this stage, deep learning approaches use efficient algorithms for hierarchical feature extraction that best represent data rather than handcrafted features [2].

Recent advances in image processing have contributed to the progress of rapidly evolving technological systems. Especially in the field of health, image processing has increased its popularity. Deep learning is an approach that contributes more in terms of time and performance compared to the existing methods. While the existing methods are used to process single layer images, the deep learning provides high performance results through multi-layer images. The most important feature of deep learning is that it can self-discover the parameters that need to be entered manually, which processes the images on a single time [3].

The objective of this research is to develop an open source software for deep learning based-classification of dementia in magnetic resonance imaging scans.

II. MATERIAL AND METHODS

A. Dataset

In this research, Open Access Series of Imaging Studies-2 (OASIS-2) (https://www.oasis-brains.org/) dataset includes longitudinal MRI scans in non-demented and demented elder individuals. 3 or 4 individual T1-weighted MRI scans achieved from one scan sessions are contained for each subject. The related individuals are all right-handed and comprise men and women. 72 of the individuals were defined as non-demented during the study. 64 of the subjects were defined as demented at the time of their early visits and ensuing scans were obtained. The image dataset encapsulates 1592 MRI scans for demented and 2032 MRI scans for non-demented subjects, respectively [4].

B. Deep Learning Framework

Deep learning is an important extension of artificial neural networks and used for different applications in many scientific areas. The basic architecture of the concept of deep learning is considered as convolutional neural networks (CNNs).

According to this architecture, the first few stages consist of convolution and pooling layers. The final stage consists of a fully connected layer, followed by a classification layer. In summary, CNNs consist of multiple trainable sections placed one after the other [4].

Keras is a deep learning framework and easy-to-use high-grade Python library that can operate on TensorFlow. Keras focuses on the primary ideas of deep learning among constituting layers for artificial neural networks, their details of tensors, shapes, and mathematical explanations. TensorFlow works as backend for Keras. The sequential API and the functional API are two important types of framework. The sequential API is established on the concept of a series of layers and the most general usage of Keras. The sequential model may be regarded as a linear stack of layers [5, 6]. Keras is a high-level deep learning library written on the Python programming language. The most important feature is that it can work on the TensorFlow library. Therefore, Keras can easily perform image/video processing applications in medicine and other sciences [3]. Auto-Keras exemplifies state-of-the-art structure established on wide-ranging ensembling and deep learning rules. Auto-Keras is employed to model the artificial neural approaches for constructing better and more understandable deep neural networks for a desired task. Additionally, Auto-Keras uses deep convolutional neural networks (CNNs) constituted by many layers [7].

CNNs are the most advanced state of neural network structures. CNNs are a deep learning architecture inspired by the natural visual perception mechanism of living things. CNNs structure include convolution, pooling, recovery and feed forward layers. The main purpose of using deep learning algorithms is to learn the features by itself. CNNs have begun to use commonly in different fields over the last years due to its capacity to automatically explore and classify features in data [8, 9].

There are a total of 3624 MRI scans for demented and non-demented subjects. 2944 of them were used in the training phase and the remaining 680 were utilized in the testing phase. In image preprocessing stage, image rotation, changing width/length, truncating images, zooming, horizontal/vertical switch, rescaling, etc. are performed by classes/functions of the Keras/Auto-Keras deep learning neural network library. Hyper-parameters of the model are tuned by Bayesian optimization technique [10, 11]. Performance assessment of the model is performed based on the metrics described in the following sections. The flow charts and detailed information of the constructed model are depicted in Figures I-a and I-b.

C. The Developed Software

In the development of this software, Python programming language and its libraries (TensorFlow, Keras, Sklearn, OpenCV, Pandas, NumPy, MatPlotLib, and Flask) are used. The open source software can be accessible at http://biostatapps.inonu.edu.tr/DSY/. The developed software has two main web pages: English and Turkish languages. The screenshots of the web pages are given in Figures II and III. In the web pages, introduction, image upload and classification result areas are present.

D. Evaluation Metrics

Performance evaluation of the model constructed by deep-learning framework is performed with respect to accuracy, sensitivity, specificity, positive and negative predictive values together with 95% confidence interval (CI) levels in training and testing stages. 95% confidence interval values for all the metrics are calculated by our developed software [12]. The formulas for these performance criteria are given below.

Accuracy = (TP + TN) / (TP + TN + FP + FN)
Sensitivity = TP / (FN + TP)
Specificity = TN / (FP+TN)
Positive predictive value = TP / (TP+FP)
Negative predictive value = TN / (TN+FN)

In these formulas, TP represents the correct positive number, TN defines the correct negative number, FP explains the false positive number and FN describes the false negative number [13].

III. EXPERIMENTAL RESULTS

Evaluation metrics with 95% CI of the model constructed by Keras in training and testing are presented in Table I. When the evaluation metrics are regarded, all the values are considerably high for classifying the dementia.

TABLE I. EVALUATION METRICS OF THE MODEL CONSTRUCTED BY KERAS

Metric	***Training [Value (95% CI)]***	***Testing [Value (95% CI)]***
Accuracy	0.996 (0.992-0.998)	0.963 (0.946-0.976)
Sensitivity	0.997 (0.993-0.999)	0.949 (0.918-0.971)
Specificity	0.995 (0.990-0.998)	0.973 (0.952-0.987)
Positive predictive value	0.994 (0.988-0.997)	0.966 (0.939-0.981)
Negative predictive value	0.997 (0.993-0.999)	0.961 (0.937-0.976)

When a T1-weighed MRI image for a patient with dementia is uploaded to the web-based software, the outputs of the classification prediction are obtained in the following Figure IV. The same result can be obtained in Turkish for the patient concerned.

When a T1-weighed MRI image for an individual with non-dementia is uploaded to the web-based software, the following Figure V outputs the result of classification prediction. Similarly, the identical result can be achieved in Turkish for the related non-demented person.

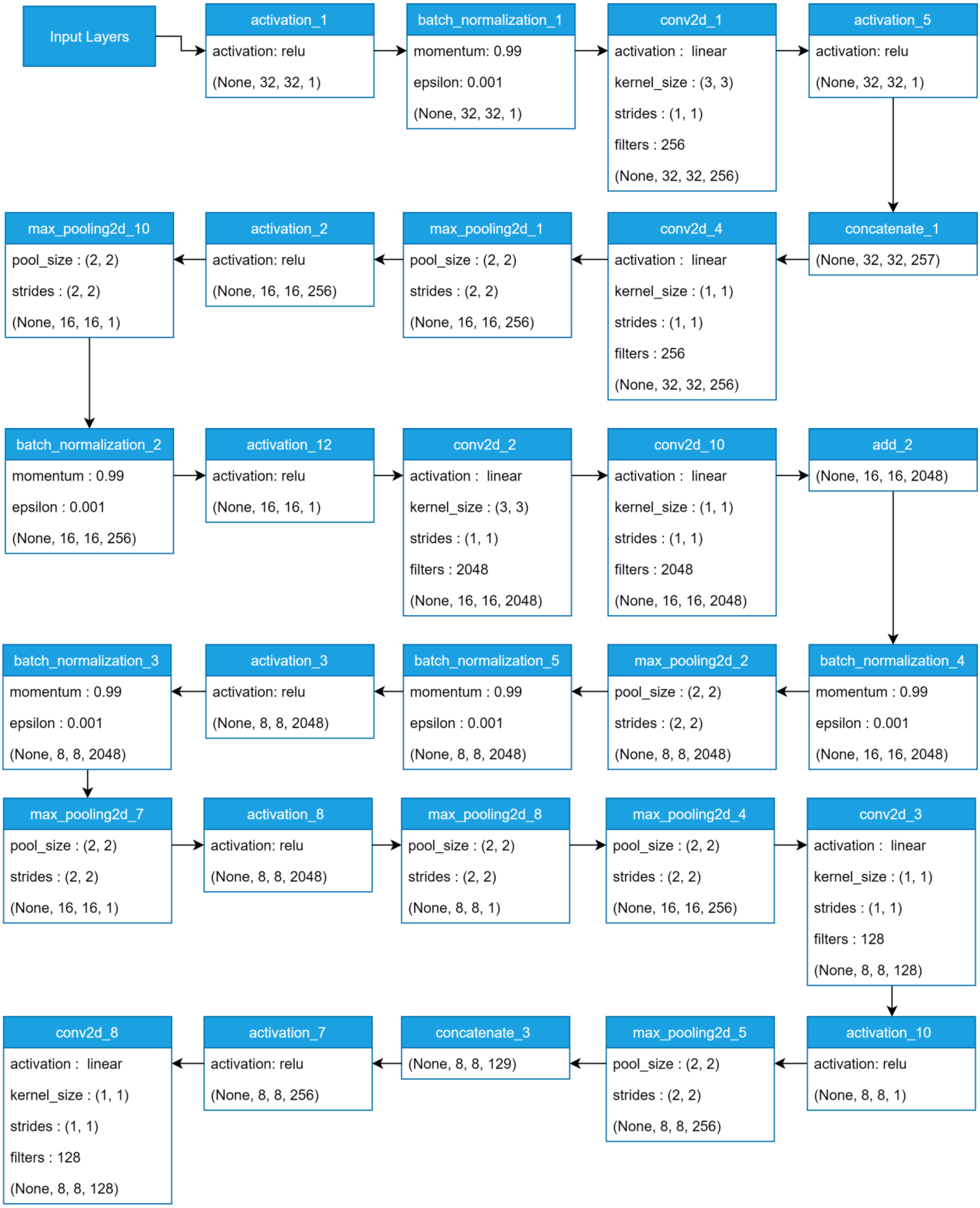

Fig. I-a: The flow chart and detailed information of the constructed model (to be continued)

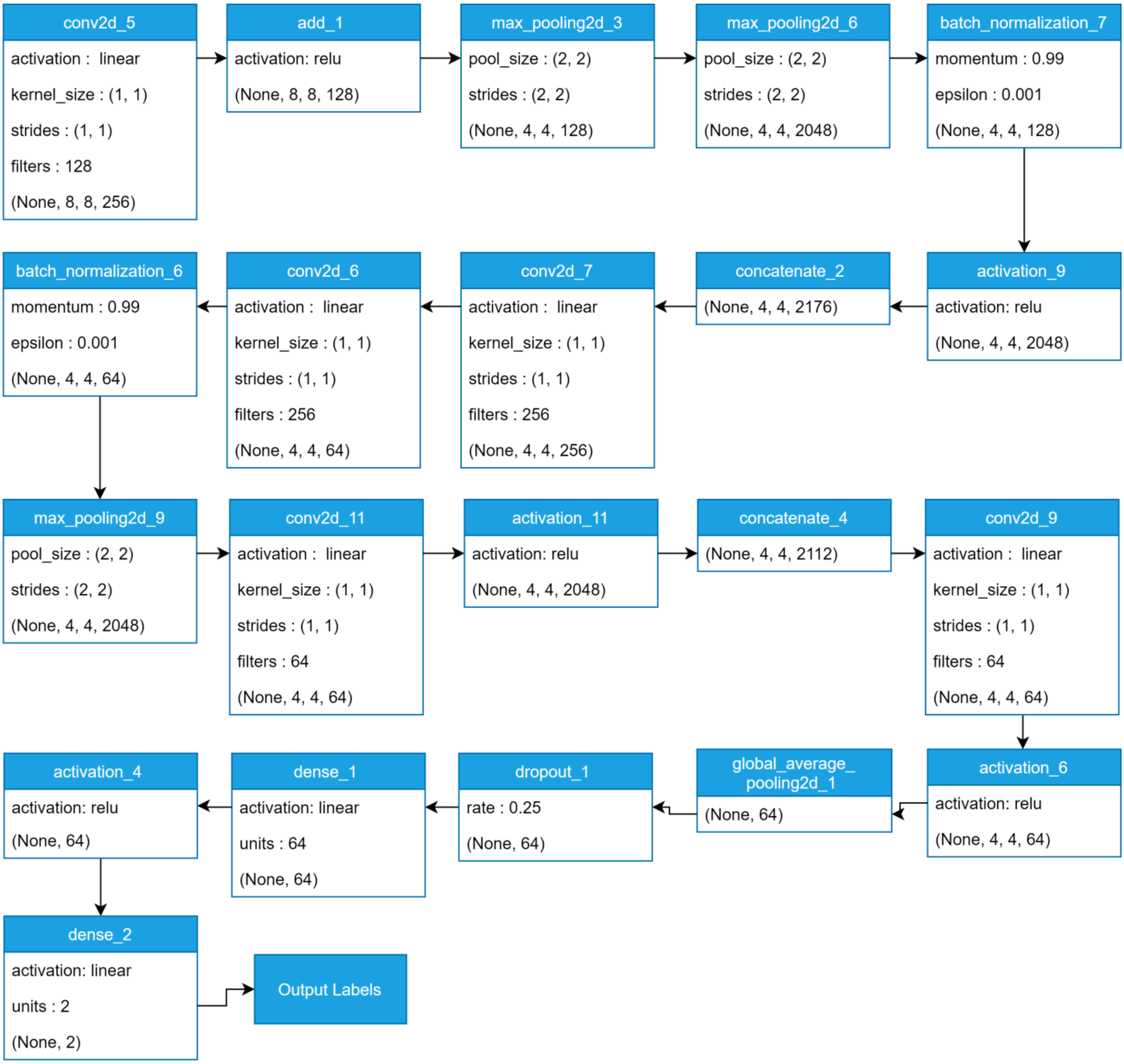

Fig. I-b: The flow chart and detailed information of the constructed model (continuation of Fig. I-a)

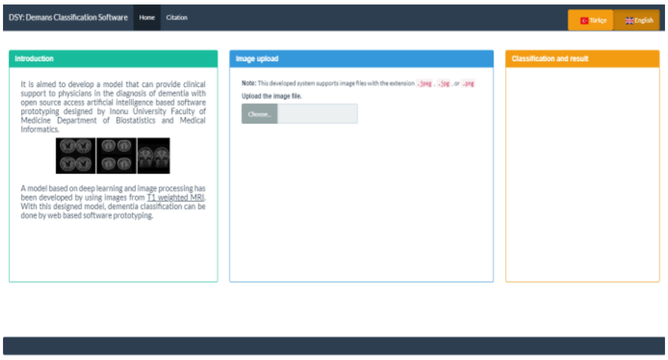

Fig. II: Screenshot of the English web page

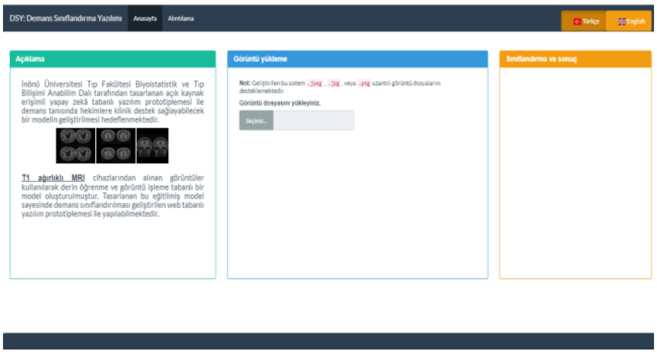

Fig. III: Screenshot of the Turkish web page

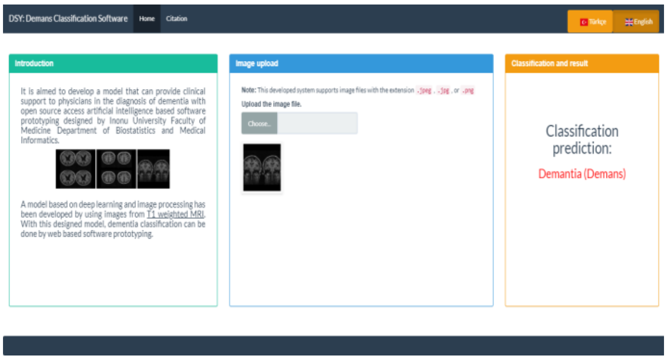

Fig. IV: The output of the classification prediction for a patient with dementia in English

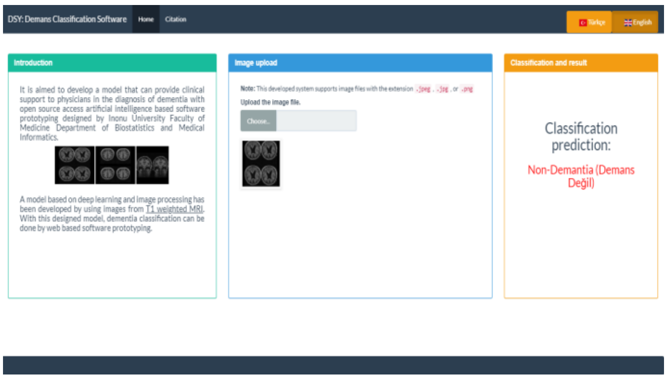

Fig. V. The outputs of the classification prediction for an individual with non-dementia in English

IV. CONCLUSION

Deep learning has led to great improvements in many areas in recent years. The most important factor for this is that there are many library files written in various programming languages (Java, C #, C ++, Python, etc.) on deep learning. "TensorFlow, Lasagne, Keras, MXNet, Caffe, Torch, etc." are the most preferred libraries. These libraries support many learning models such as multilayer neural networks [3, 14].

In relation to deep learning, the current research intends to develop an open source software for deep learning based-classification of dementia in magnetic resonance imaging scans. The calculated performance metrics demonstrate that the proposed Keras deep learning model can be used to successfully separate dementia patients and healthy individuals based on the T1-weighted MRI scans. In the researches that will be carried out in the following stages, it may be suggested to develop artificial intelligence based-classification models and softwares that can classify the types of dementia (i.e., vascular, Lewy bodies, frontotemporal, Alzheimer, etc.) and non-dementia status.

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