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DIAGNOSIS OF STUDY URODYNAMICS RESULTS OF BLADDER DISEASE BASED ON DEEP LEARNING

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Abstract

Problems in the urinary tract can challenge the quality of life of humans, so that with proper and timely diagnosis of those problems, can be frequent urination, kidney stones and bladder stones or even prostate cancer or eliminate Prevented the kidneys from going. With the correct and quick diagnosis of the disease, the doctor can start the appropriate treatment and the patient will have a good quality of life. Today, to help doctors, artificial intelligence and computer-aided diagnosis (CAD) can play an important role, now deep learning has shown promising performance in computer vision systems [12]. However, no similar action has been taken so far, in this paper, we propose an enhanced approach for classifying diseases related to the urinary tract types using 1 dimensional convolutional neural network. A urologist clinic in Tehran, Iran, has donated the results of its research tests. We evaluate the proposed model on a benchmark dataset containing 1168 test of 3 Diseases related to the urinary tract types (Spastic Neurogenic Bladder, Neurogenic Bladder, and Flaccid Neurogenic Bladder). We have achieved 85 percent accuracy and so far no similar work has been done on this collection.

Keywords: One-dimensional convolutional; Bladder Urodynamic Study; Deep learning; Neural network; Urodynamic test; Bladder strip.

1. INTRODUCTION

the study and measurement of urine flow in the urinary tract is called urodynamic test or bladder strip. bladder tape is a doctor's test that is used to evaluate bladder and urethra function, bladder tape is useful in the diagnosis of functional abnormalities of the lower urinary tract such as urinary incontinence and obstruction of the urethra. In men, prostate duct weakness can be diagnosed by blocking or confirming the obstruction of the bladder opening, using this test, kidney and bladder stones can be prevented.

The outputs of this experiment include frequency and volume diagram of urine, recording the volume and frequency of urination by the patient, evaluation of pressure and flow of urine output, estimation of urine residuals by ultrasound, cystometry of outpatient bladder strips, and examination of conduit pressure [2].

The purpose of the bladder tape is to answer clinical questions to assess bladder and urethral function. The term urodynamics covers the study of lower urinary tract disorder from simple to complex and includes the following: in the urodynamic test or bladder strip for urinary incontinence, bladder function is evaluated [3].

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These tests vary per person. Test steps include: the bladder should be full. at the time of discharge of urine in the container, the volume of urine and the amount of bladder drainage should be measured. the tcatheter enters the bladder, and the volume of urine left in the bladder is checked. the bladder may be filled with water through the catheter, and the person will then have to urinate. the amount of bladder fluid is measured.

Diagnosing the type of disease based on test results is a challenging, error-prone, and highly specialized task that depends on the experience of the urologist, and most importantly, it is a time-consuming procedure, In addition, experiments may have very different results and there are not enough visible signs in the experiments to make decisions and help to be accurate, so it can be concluded that human diagnosis is likely to cause errors.

In addition, misdiagnosis of the type of disease can be a serious problem, because it can endanger the patient's quality of life, and correct diagnosis helps the patient to start the right treatment and get treatment immediately, and life is happier and Have no harm.

Accordingly, this necessitates an urgent need for artificial intelligence (AI) as a basis for the development and design of a new and innovative computer-aided diagnosis (CAD) system, with the aim of easing the workload for the diagnosis and classification of diseases and Acts as an aid to physicians and urologists.

During the last decade, Convolutional Neural Networks (CNNs) have become the de facto standard for various Computer Vision and Machine Learning operations. CNNs are feedforward Artificial Neural Networks (ANNs) with alternating convolutional and subsampling layers.

The results of medical tests are very important and sometimes rare or specific, and for processing the signals from these tests, 1D CNNs have recently been proposed and immediately achieved the state-of-the art performance levels in several applications such as personalized biomedical data classification and early diagnosis, structural health monitoring, another major advantage is that a real-time and low-cost hardware implementation is feasible due to the simple and compact configuration of 1D CNNs that perform only 1D convolutions (scalar multiplications and additions) [1]. 1D convolutions is also widely used in the diagnosis of diseases and other industrial applications [4-11].

The importance of this research includes several aspects:

1) To date, no similar work has been done using artificial intelligence and machine learning models to control or diagnose urinary tract diseases. The reason for this seems to be the difficulty of collecting and processing the relevant data set.
2) The results presented by this article will be a starting point for future work. Modeling and data processing can be measured and improved in various ways.

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Briefly, the contributions of this paper are as follows:

We propose an enhanced approach for classification diseases related to the urinary tract types using 1 dimensional convolutional neural network. we evaluate the proposed model on a benchmark dataset containing 1168 test of 3 Diseases related to the urinary tract types, also, we evaluate the proposed model based on various criteria such as accuracy, precision, recall, f1 score and balanced accuracy. Using these types of criteria, we can clearly show the test result, the proposed deep learning model we have achieved 85 percent accuracy and so far no similar work has been done on this set.

2. MATERIALS, METHODS AND MODEL

2.1. Dataset and Disease

In order to use artificial intelligence in the control and diagnosis of urinary tract disease, we in this article, we have used the results of a series of tests performed on 1168 people during for seven years in a clinic located in Tehran-Iran.

The results of these experiments were in the form of graphs and related tables, Including frequency and volume chart of urine, recording the volume and frequency of urine by the patient, evaluation of urine pressure and flow rate, estimation of urine residue, urine pressure and other related information, an example of Urethral pressure profile test results can be seen in Figure 1, which includes information Relevant are Puller speed, Functional urethral length, Resting bladder pressure, Maximal urethral pressure. Also, an example of the results of the Pressure-flow study can be seen in Figure 2, which includes relevant information such as Infused volume, Bladder filling, First sensation, First desire, Normal desire, Strong desire, an example of Uroflow test results can be seen in Figure 3, which includes information related to Peak flowrate, Time to peak flow, Voided Volume, Average flowrate.

A bladder strip is a test that looks at how urine is stored by the bladder and excreted from the bladder. Also, the function of the sphincter and bladder muscles and problems such as urinary incontinence, frequent urination and urinary urgency can be examined with this test. There are various nerves in the bladder area that control the muscles of the urinary tract and allow people to hold their urine as long as they empty it voluntarily.

This process is naturally controlled by the brain and a nerve message is sent from the brain to the bladder when urinating. In fact, urodynamic tests can detect and then control any type of bladder problem.

Most urodynamic tests focus on the bladder's ability to empty urine continuously and completely, as well as abnormal bladder contractions that cause incontinence. Demonstrates urination. In this test, the amount and speed of urine flow is automatically measured and the patient is asked to urinate in a special container. This device is connected to a computer that automatically graphs. The corresponding is plotted by a Euro flowmeter, which shows the changes in urine flow rate from second to second.

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This graph also shows the maximum speed of urine flow and the time it takes to reach its peak. This test becomes unusual when the bladder muscles are weak or there is obstruction in the urinary tract. We provide this information in coordination with specialist physicians and technicians. Which we have summarized in the form of a CSV file's.

This file consists of 4 groups, 1 group belongs to healthy people who have no problems, and the other 3 groups include 3 diseases are related to different types of urinary tract (spastic neurogenic bladder, neurogenic bladder, and flaccid neurogenic bladder).

Spastic neurogenic bladder, is a bladder whose function is impaired due to damage to the bladder nerves and the failure of the nerve message to reach it. During the test, the bladder reacts quickly and it is practically impossible to inject into the bladder due to severe contraction.

The neurogenic bladder is also very similar to the spastic neurogenic bladder, except that serum can be injected into the bladder and the bladder does not react rapidly. In this type of patient, the bladder has less capacity than normal but the activity of the bladder wall muscles is abnormally high, resulting in frequent urination and urinary incontinence.

Control and treatment of the neurogenic bladder restores control of the urinary tract.

Flaccid neurogenic bladder, in these patients, the bladder has enough capacity or even more to store urine, but the bladder is unable to empty urine due to poor function of its wall muscles. As a result, these people usually do not feel like urinating and face many problems, including dripping urine.

One of the neurological symptoms of bladder is the inability to control urination, in addition it can cause increased urination, It also has other symptoms, such as: dripping urine flow, inability to empty the bladder completely, feeling of pressure when urinating, lack of bladder control, increased urinary tract infections, lack of diagnosis of bladder fullness, Not diagnosing the disease in time , In addition to reducing the quality of life, it causes urinary retention in the kidneys or bladder and increases infection in the urinary tract and kidneys and causes stones in the bladder and kidneys and eventually causes kidney failure.

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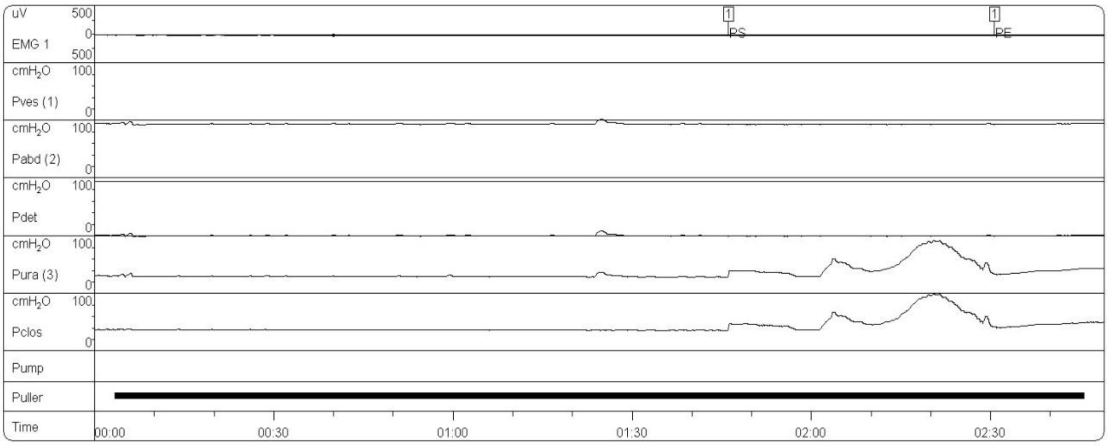
Urethral pressure profile report

Gender:	Male	Investigation nr:	
Date of birth:		Private clinic:	Dr
Patient number:		Investigator:	Dr
Investigation date:		Referred by:	Dr



Urethral pressure profile results

Puller speed	60 mm/min
Bladder filling	0 ml

Profile results

Rest profile	**1**
Resting bladder pressure	29 cmH_2O
Max. urethral closure pressure	64 cmH_2O
Maximal urethral pressure	93 cmH_2O
Functional urethral length	45 mm

Marker overview

Marker name	Time	Pves (1)	Pabd (2)	Pura (3)	Pdet
Profile start	0:01:46'10	-8	-7	29	-1
Profile end	0:02:31'65	-8	-7	34	-1

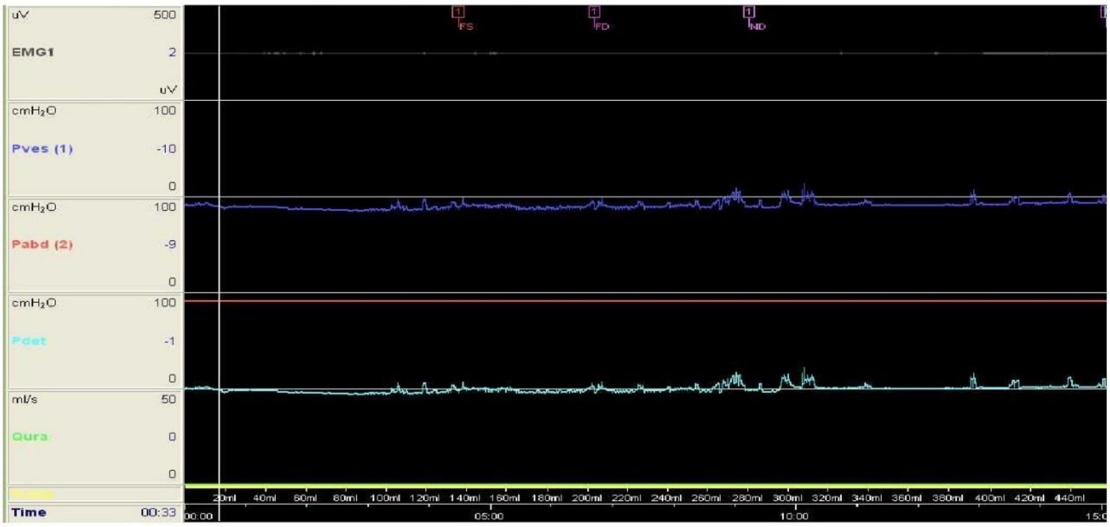


Figure 1: Example of Urethral pressure profile test results.

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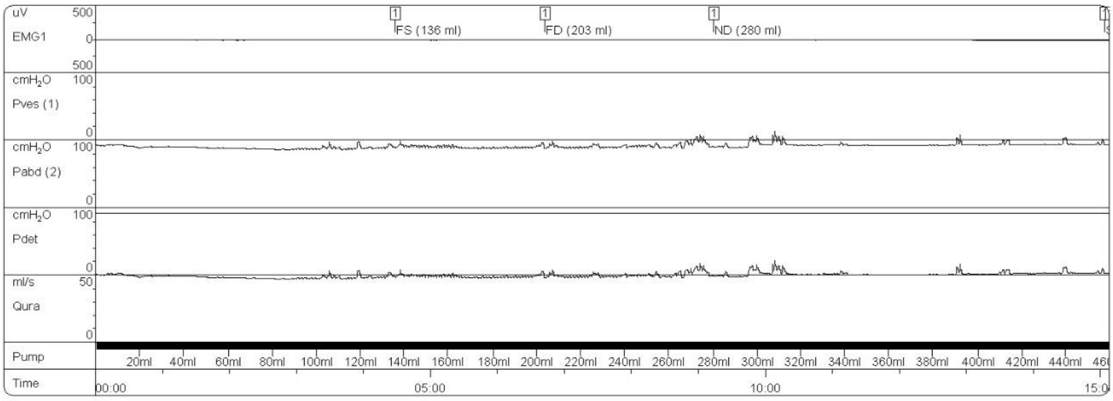
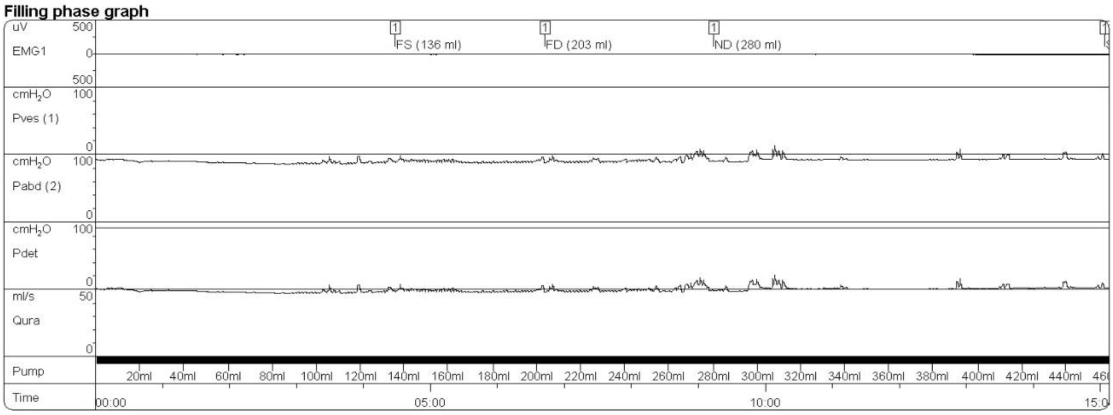
Pressure-flow study report

Gender:	Male	Investigation nr:	01
Date of birth:		Private clinic:	Dr
Patient number:		Investigator:	Dr
Investigation date:		Referred by:	Dr



Filling phase graph



Filling phase results

Infused volume	460 ml
Volume lost through leakage	- ml
Bladder filling	460 ml

Sensation results

Sensation	Bladder filling	Vesical pressure	Detrusor pressure
First sensation	136 ml	-12 cmH_2O	-3 cmH_2O
First desire	203 ml	-13 cmH_2O	-4 cmH_2O
Normal desire	280 ml	-11 cmH_2O	-2 cmH_2O
Strong desire	458 ml	-7 cmH_2O	2 cmH_2O

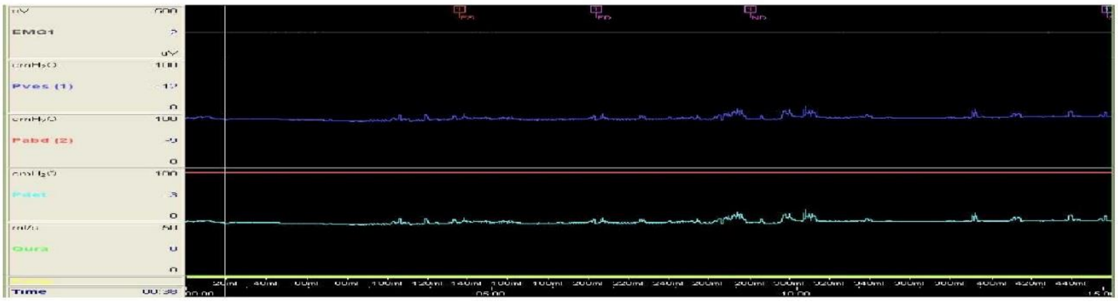


Figure 2: Example of Pressure-flow study results

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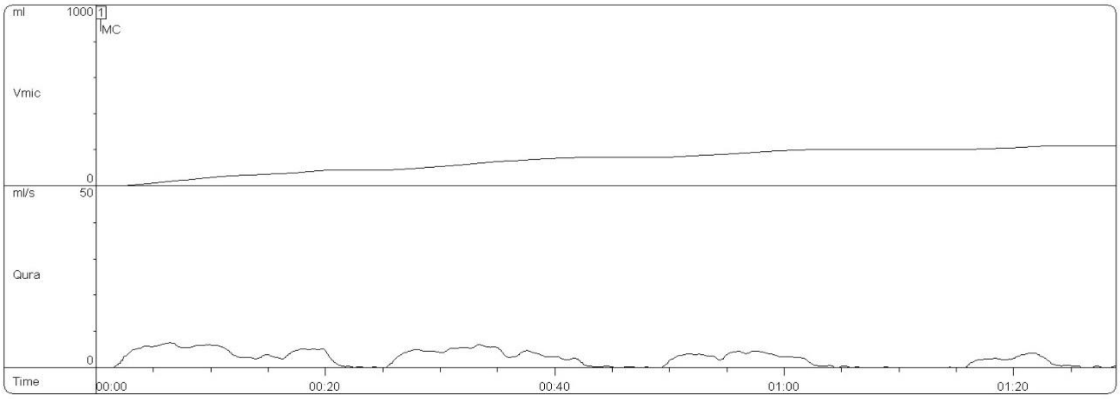
Uroflow report

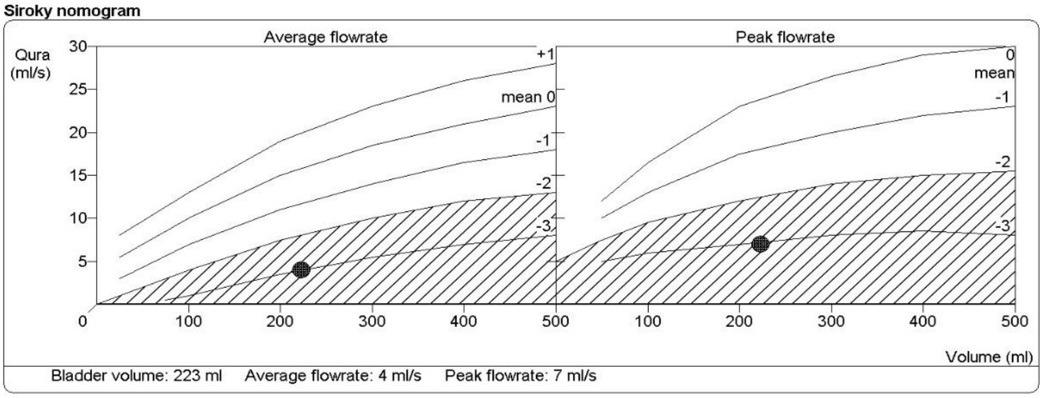
Gender:	Male	Investigation nr:	03
Date of birth:		Private clinic:	Dr
Patient number:		Investigator:	Dr
Investigation date:		Referred by:	Dr



Uroflow results

Peak flowrate	7	ml/s
Time to peak flow	5	s
Voided volume	223	ml
Flow time	58	s
Voiding time	83	s
Average flowrate	4	ml/s

Siroky nomogram



Marker overview

Marker name	Time	Vmic	
Miction command	0:00:00'40	0	

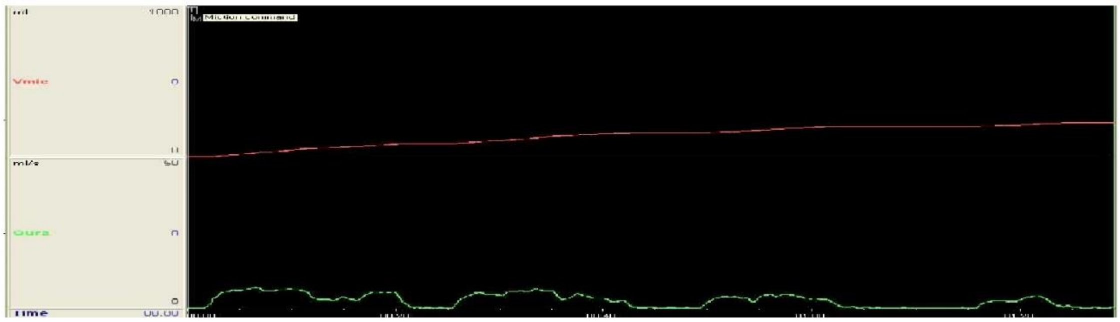


Figure 3: Example of Uroflow test results

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2.2. Preprocessing of the dataset

To use the tests results, with the opinion of physicians and specialized technicians, to determine the important parameters and after extracting these parameters, information related to, we inserted the graphs into an CSV file's, We labeled three diseases with people without the disease, including 1 for healthy people(normal), 2 for people with spastic neurogenic bladder, 3 for neurogenic bladder, and 4 for flaccid neurogenic bladder. The total Dataset is labeled for 1168 people.

2.3. Model 1D convolutional neural network

We used a 1D CNN model and placed two 1D layers with Filter_size = 16 and Kernel_size = 3 with the ReLU activation function. Then we applied the Max pooling 1D layer (Pool_siza = 2) and after that applied the two 1D layers again with Filter_size = 8 and Kernel_size = 3 with the ReLU activation function. We did Max pooling again and then Flat and after that we did three Dense layers with sizes 64, 32 and 4. The first two layers are executed with ReLU activator function and the last layer with Softmax activator function. It should be noted that the reason for applying the last layer with Filter_size = 4 is due to the existence of 4 classes (normal, spastic neurogenic bladder, neurogenic bladder, and flaccid neurogenic bladder). This model uses Optimizer Adam and Luss = 'sparse_categorical_crossentropy', We normalized our data set with Norm = L2 using the Sklearn libraries, and also divided it into a train and test with a ratio of 20 to 80. The above model is taught in 10 Folds and each Fold with 100 Epoch and with Batch_size = 16. In Figure 1 you can see an example of the One-dimensional convolutional that we used to implement the model.

ReLU and softmax functions are defined as follow [8]:

$$ReLU(x) = \max(x, 0) \qquad (1)$$

$$Softmax(y = k|x) = \frac{e^{w_k^T x + b_k}}{\sum_{l=1}^{K} e^{w_1^T x + b_1}} \qquad (2)$$

Where the output is k's softmax value, K is the number of classes, w is the weight for input x and b is the bias.

A loss function should be assigned to a machine learning model for determining how the model is optimized to gain the best fit with the training dataset. Sparse_categorical_crossentropy in Keras is applied as a loss function in the training procedure. Adam optimizer with a learning rate of $1e^{-2}$ is applied for optimizing the loss. The crossentropy loss function is defined as follows:

$$L_{crossentropy} = -\frac{1}{M}\sum_{m=1}^{M}\sum_{k=1}^{K}\left[\delta(y^{(m)} = k)\log\left(\frac{e^{w_k^T x^{(m)} + b_k}}{\sum_{l=1}^{K} e^{w_1^T x^{(m)} + b_1}}\right)\right] \qquad (3)$$

Where M is the number of samples, k is the number of classes, w is the weight for input x and b is the bias.

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Since we aim to make a re-trainable model, it can accept completely different datasets for different patient outputs. The output patient types here can be altered if the model is re-trained with customized patient types for prediction. All layers, filter sizes, the numbers of filters and other parameters can be further tuned for better model performance.

2.4. Model comparison

We compared the performance of our model with other supervised classification models, including the top three supervised models, which are SVM, XGBoost and Random Forest.

Loss function sparse_categorical_crossentropy is applied to measure the loss. Adam optimizer with a learning rate of 1e^(-2) is applied for optimizing the loss. A batch_size of 16 and epochs with 100 steps per epoch are applied to our training process.

The linear activation function and hinge loss for the SVM model are defined as follows:

$$Linear(x) = x \quad (4)$$

$$L_{\text{hinge}} = \max(0,1 + max w_t x - w_y x)(t \neq y) \quad (5)$$

Where t is the labels other than y, w is weight and x is the input.

As for the XGBoost and the Random Forest classifiers, both functions were applied directly from Python package scikit-learn with default parameters was used.

2.5. Model performance evaluation

To evaluate the performance of the Model 1d, SVM, XGBoost and Random Forest models, we applied 10-fold cross-validation (10F CV) to the data set. Each time we randomly provided 0.2 of the test data and 0.8 of the entire data set, and we did this 10 times.

The dataset was first grouped by their own Sickness type labels, and in each Sickness type 10 folds of the Sickness were first generated randomly, and then grouped across all Sickness types to generate the 10-fold Sickness in the whole data set, which is also called as stratified cross validation.

We used different performance measures in the stratified 10F CV to evaluate the Model 1d, SVM, XGBoost and Random Forest models. The first one is model accuracy (ACC), which is the percentage of the correct predictions in the labeled data set; The second one is the F1 score, which is the harmonic mean of precision and recall of the labeled data set. The terms are calculated as follows:

$$Precision = \frac{TP}{TP+FP} \quad (6)$$

$$Recall = \frac{TP}{TP+FN} \quad (7)$$

$$F_1 score = 2 . \frac{Precision . recall}{Precision + recall} \quad (8)$$

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Where true positive (TP) indicates a correctly predicted Sickness type, false positive (FP) indicates an incorrectly predicted Sickness type, true negative (TN) indicates that a non-given Sickness type is correctly predicted while false negative (FN) indicates that a non-given Sickness type is incorrectly predicted.

3. RESULTS

3.1. Model Construction

To build a supervised learning system for predicting a variety of urinary tract diseases, we introduced a 1D model that is a retrainable 1D-CNN model (Figure 4). Our model is not only able to learn the expression values of the disease, but can also detect people without the disease. After designing the model framework, we selected several optimized meta-parameters by performing several combinations of different parameters from filter size in cross-layers to loss function, and finally adjusted the best meta-parameter values.

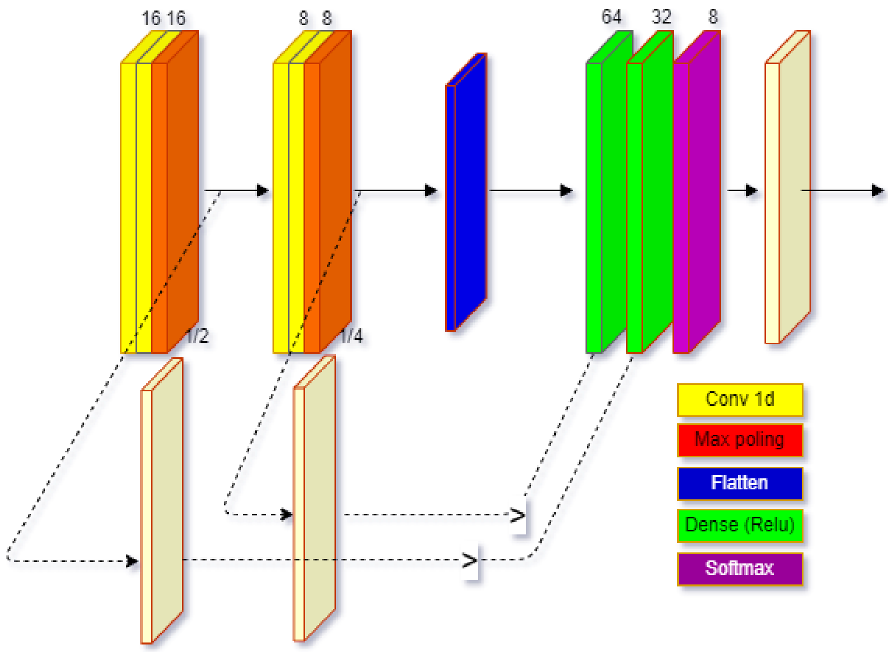

Figure 4: The proposed model retrainable 1D-CNN

The results from the Confusion Matrix (Figure 5) show us how well the performance of the trained model can predict each type of disease. In general, this model can accurately predict both the health of the urinary tract and the three diseases of the urinary tract in each person. All types of diseases predicted by the model have AUC values greater than 85%, which indicates that the model has a high ability to assign different types of diseases. You can see the results for model accuracy and model loss in Figure 6.

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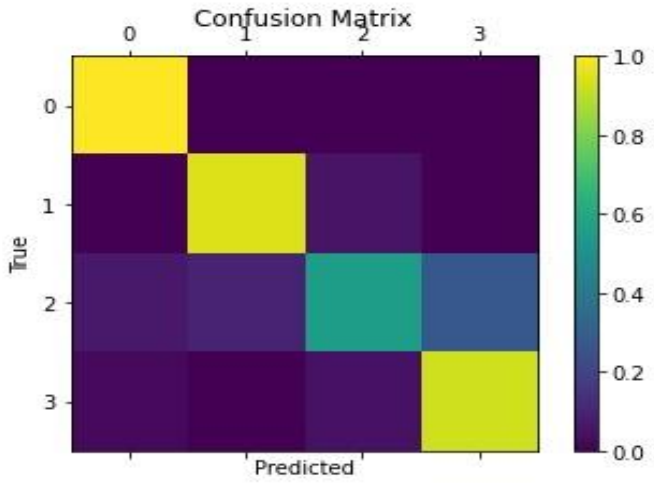

Figure 5: The results from the Confusion Matrix

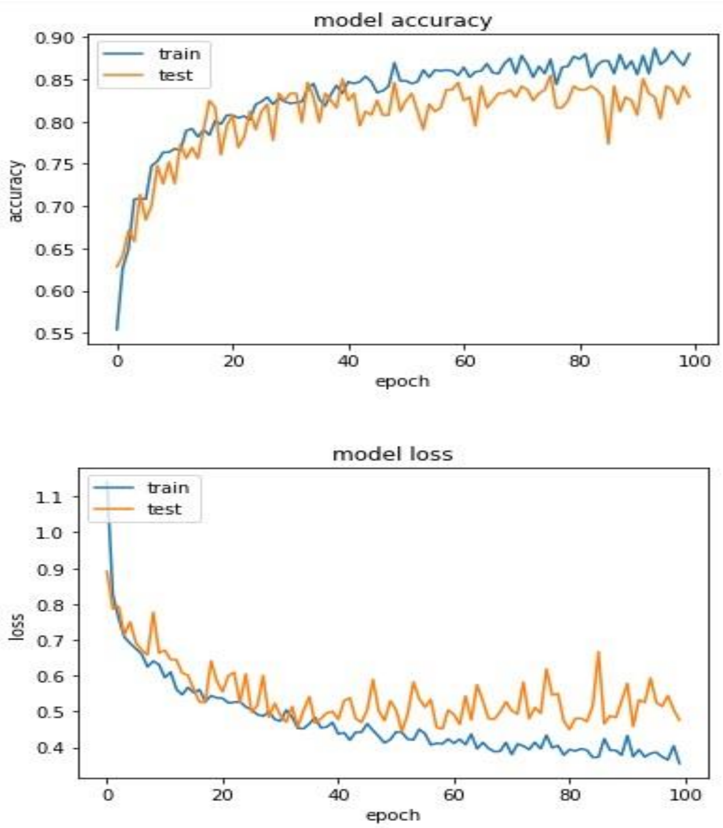

Figure 6: The results for model accuracy and model loss

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3.2. Comparison of model performance

Table 1, shows the average accuracies and F1 scores of the Model 1d, SVM, XGBoost and Random Forest models models in the 10F CV. The average accuracy of the Model 1d reached up to 85% and is the highest accuracy among the three models. When considering F1 scores, the Model 1d also performed better than other Three models. For both metrics the Model 1d performed the best among the Four models, indicating that our Model 1d is a robust and good model. The results of accuracy and comparison can be seen in Table 1.

Table 1: The results of accuracy and comparison.

Accuracy:	0.8520598290598291			
Recall:	0.8595329827136333			
Percision:	0.8502114623166625			
F1 Score:	0.8508807231620719			
	Precision	**Recall**	**F1-score**	**Support**
0	0.85	1.00	0.89	23
1	0.93	0.95	0.94	96
2	0.85	0.84	0.88	73
3	0.86	0.93	0.87	42
accuracy			0.86	234
macro avg	0.86	0.87	0.88	234
weighted avg	0.87	0.88	0.88	234

3.3. Software Implementation for Model

In order to further evaluate the performance of the proposed supervised model, we used the trained model to predict various urinary tract diseases from our database, which includes the results of experiments on 1168 individuals and we used them after preprocessing the dataset and doing the labeling.

All code is written in Python 3. The program can be run in Linux and Windows environments. The advantage of our research and model is that other researchers can use this dataset as well as the code of this article as a reference for further research, based on their future algorithms, and also other researchers can use the model (code) with research needs expand or adapt themselves.

4. DISCUSSION

In this study, we used a very important and unique data set to collect data from the results of experiments on 1168 people in a clinic in Tehran. This set includes three urinary tract diseases as well as healthy individuals. We processed this data set, and finally we monitored a deep convolutional neural network to predict a variety of urinary tract disease subsets with retraining capabilities, adjustable outputs, and implementation.

We did Python. This article focuses on the presentation of this data set and also on the development of a model and its implementation with software. We have also provided the ability to generalize the model to predict other diseases of the urinary tract. We have shown that using artificial intelligence and machine learning, it can classify three diseases related to

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the urinary tract and can also classify healthy people. It should be noted that supervised models should not always be superior to the approaches of unsupervised models. Unsupervised methods and models are also accurate in identifying the types of diseases when large amounts of data are available.

In summary, our proposed model provides a one-dimensional CNN reference model for data processing and diagnosis of urinary tract diseases. Our model can be expanded and retrained. The data set presented in this paper can be a very important reference for other researchers to use it to develop models.

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