Federated Learning Application on Depression Treatment Robots(DTbot)

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***Abstract*—Depression is one of the most prevalent psychiatric disorders and an important public health problem. Its etiology is multifaceted, and the specific pathophysiological mechanisms are still unclear. At present, the main treatment methods for depression are medication, psychotherapy and physical therapy, and clinical applications usually combine two or three methods. Psychotherapy is currently mainly oriented towards the traditional face-to-face communication with psychologists, and is rarely combined with the current rapid development of technology. In this paper, we aim to design an intelligent robot that incorporates deep learning methods to help doctors treat patients more efficiently. The problem is that the current models of robots are trained by uploading data to a server, and then having the server train the robot. There are disadvantages of this approach. First, patient videos and conversations are private information. So uploading those private information to the server can lead to patient information leakage, which is bad. Second, the data recorded in daily life, including audio and video, are very large files that are slow to transfer and tend to cause package loss and other problems in the process. Training a multi-robot model in combination with federal learning would be a good solution to these two problems. The article combines federal learning with basic deep learning methods to design a depression treatment robot(DTbot) that can treat patients with more privacy and efficiency while handling their personal information.**

Keywords—robot, federated learning, deep learning, depression treatment

I. INTRODUCTION

In the current fast-paced society, depression has become a common mental illness, usually manifested as long-term (more than two weeks) depression, accompanied by various types of loss of interest and sleep disorders [1]. Due to the suicide rate of depression patients is very high [2], the diagnosis and treatment of depression have been widely concerned by society. As of 2020, there are more than 264 million people suffering from depression worldwide, across all age groups and countries [3], and the number of patients has increased by more than 18% from 2005 to 2015 [4]. However, depression can be detected through early diagnosis, combined with psychological counseling and antidepressant drugs, which can be controlled and cured clinically [5].

However, there are many obstacles to treating depression. First of all, the Chinese Guidelines for the Prevention of Depression states that the relapse rate of depression is as high as 80% [6]. Usually, the psychiatrist's diagnosis of whether a patient with depression is fully recovered is mainly by asking about recent symptoms and mood. Due to the lack of objective evaluation methods for the diagnosis of depression, some patients who conceal their depression are mistakenly diagnosed as recovered patients; thus, the misdiagnosis rate is high. In addition, because of the development of big data technology, the diagnosis and treatment of depression is not only the traditional way of going to the hospital to consult the doctor. The treatment of mild depression basically depends on some mobile medical applications for personal mental state recording and monitoring; the moderate and severe depression usually need to be hospitalized for a period of time to take comprehensive treatment for disease monitoring [7][8]. In this case, the patient's daily mood and even life details will be exposed to the hospital's monitoring, and the patient's personal information and life privacy will be uploaded to the remote server for doctors to observe and diagnose. At present, the technology of privacy protection on the internet is not perfect, so that the patient's life privacy and personal information are likely to be leaked.

Therefore, for depression patients, it is very important to make a correct diagnosis on whether the depression patient has recovered completely and protect its privacy. There are some people who have done some related work. Some of them use machine learning to help diagnose depression [9]. Some researchers use micro-expression recognition to help doctors determine whether a patient suffers from depression at the first visit [10] Nevertheless, few people pay attention to the fact that patients with depression often conceal their negative emotion to some extent, which leads to doctors making the wrong diagnose that the patient does not have depression or that the depression has fully recovered. Furthermore, depression patients are highly nervous and sensitive to various things, so that monitoring throughout the day will cause them to be more stressful, which will lead to more serious time. In the related research, few people combine the methods of federated learning and deep learning to more efficiently protect the depression patients' personal information and life privacy under the premise of accurately diagnosing whether depression patients are fully recovered. However, this is a very important function in the treatment of depression.

Currently, machine learning and deep learning algorithms are in a very popular period and the application of robots is ubiquitous. However, the common robots in hospitals are service robots that only navigate. Therefore, through the combination of machine learning and deep learning, this article has designed an auxiliary treatment robot for depression. The main functions of the robot are as follows. Firstly, the voice sensor is used to analyze whether the patient's emotions are positive or negative when talking with the patient. This is achieved by using machine learning emotion analysis methods. Thus, it can record the patient's daily mood changes to determine the patient's condition. Secondly, the video sensor is used to observe the micro-expressions of patients while chatting. It can use machine learning methods for micro-expression recognition to determine the patient's feeling. Finally, by comparing the patient's speech emotion and micro-expression emotion to determine whether the patient has recovered completely. Through federated learning, all data can be processed in DTbot and the model training can be completed through collaboration with remote servers instead of uploading to the remote.

The paper is organized as follows. Section I introduces the basic background and the problem definition. Section II is the related work of clinical diagnosis research on depression through federal study. Section III defines the robot model and its role in the treatment of depression. Section IV analyzes the benefits of the robot. Section V concludes the paper. Section VI is the reference.

II. Related Work

In order to protect people's data, a lot of related work has been done before. In 2015, Jakub Konen, H. Brendan McMahan and Daniel Ramage [11] proposed to keep the training data of machine learning locally instead of uploading the data to the data center for training. In 2016, Google [12] first proposed to use the framework of federated learning to enhance data privacy and security. Wei Zhou, Yiying Li, Shuhui Chen and Bo Ding [13] raised a real-time data processing architecture for multi-robots based on the differential federated learning, called RT-robots architecture, which makes robotic tasks are processed locally in real time. Meng Hao et.al [14] propose an efficient and privacy-enhanced federated learning (PEFL) scheme for industrial artificial intelligence, which prevents private data compared with existing solutions. Not only that, participants in federated learning can realize their own local training model through collaboration with remote sites without sharing their data [15]. In 2020, Meijing Shan [16] pointed out that when patients use mobile medical applications, their privacy may be leaked due to user mis-operations or uploading data; however, through a variety of methods to prevent privacy theft, including federal learning, personal information can be effectively restricted to training equipment and users' privacy can be protected fundamentally. In addition, Yu Zhao, Jie Yang, Miao Liu, Jinlong Sun and Guan Gui [17] proposed that the video computing model based on federated learning can avoid uploading videos with large amounts of user privacy to remote platforms for data processing, thereby reducing the risk of user privacy leakage. Boyi Liu, Lujia Wang and Ming Liu [18] provided a learning architecture for navigation in cloud robotic systems: Lifelong Federated Reinforcement Learning (LFRL) to greatly improve the efficiency of reinforcement learning for robot navigation.

III. DTbot

We used federated learning on our robot model design. Federated learning is a machine learning setup. There are multiple clients collaborating with the models training under coordination with a central server, while keeping the data decentralized. Federated learning allows clients to download the basic model shared by the server, and all clients train their own model and upload updated model parameters back to the server, the server will process those parameters and then share them out again, until the process ends. Every DTbot is a client that deals with the same number of patients' data, will train those data locally and only communicate with the server when updating model parameters.

The DTbot we designed will not need to upload pictures, videos, and audios to the cloud for analysis, as those personal information may involve a lot of private photos and conversations of patients. In this era when privacy is so important, it is very important to do a good job in protecting privacy while serving human beings. So it's important to apply federal learning to our DTbot. All the robots in the Hospital can train their own data locally in accordance with the model given by the host, and send the results of relevant characteristics obtained by training back to the host for reference. This ensures that the patient data doesn't have to be moved out of the robot, and that also gets a good learning model. At the same time, it greatly reduces the amount of data transmission and improves the efficiency of the whole control system, avoiding package loss during transmission. The general design is as follows:

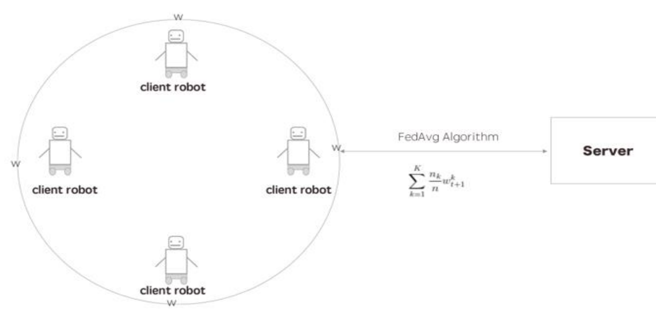

Fig. 1. General design for Dtbot.

The following picture shows an example using face recognition, and using CNN as a model of face recognition. Every robot will collect data, clean data, and train and test data, sending back those gradients of Convolutional neural network (CNN) model results to the server. Server will average all those gradients and send back the new gradient to every client, and iterate this process till the counter is done.

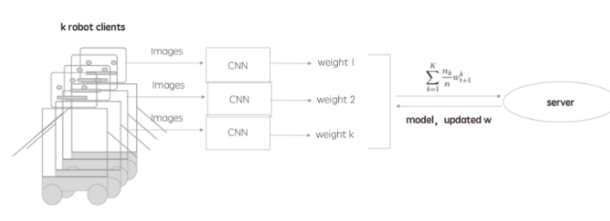

Fig. 2. Single DTbot CNN example.

A. *Preprocessing Inside of Robot before Training Model*

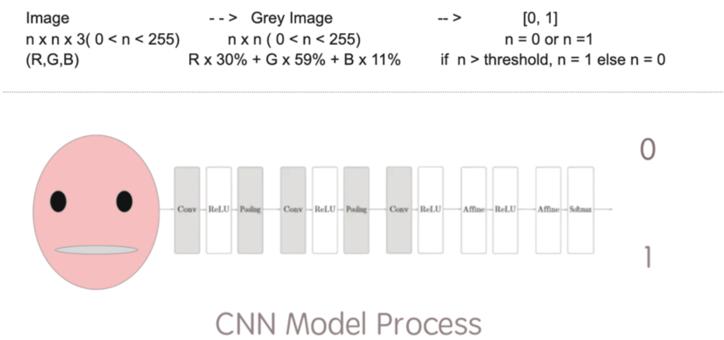

Fig. 3. CNN model process.

B. *Two Parts of the Federated Learning*

Use w represent of model

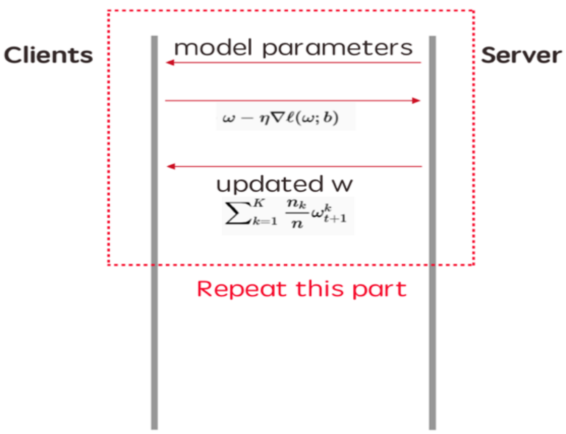

Fig. 4. Federated learning process.

C. *Federated Learning in Robot*

The Input: Images collected by DTbot

Output: Sentiment analysis result

Every DTbot focuses on the same number of patients. Eg. B represent the number of patients a DTbot focus on, there are K robots

Step 1: DTbots download model from server:

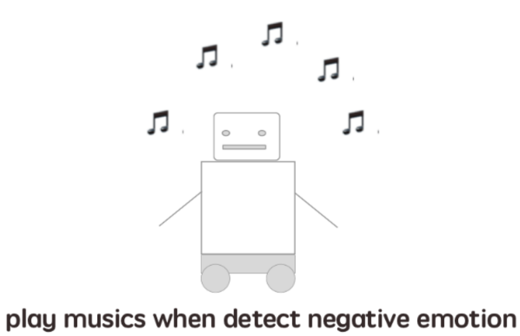

Fig. 5. Auto Music Play Bot.

K = number of DTbots

B = number of patients every DTbots focus

Initial model = w0, fixed learning rate = η

Step 2: DTbot k calculate gradient and upload to server:

Number Kth DTbot's current model = wt

gk is the gradient descent of DTbot k

$$g_k = \nabla F_k(w_t)$$

Step 3: Server aggregates all k gradients and applies the update:

$$w_{t+1} \leftarrow w_t - \eta \sum_{k=1} K \sum_{k=1}^{K} \frac{n_k}{n} g_k$$

$$K \sum_{k=1}^{K} \frac{n_k}{n} g_k = \nabla f(w_t)$$

$$w_{t+1}^{k} \leftarrow w_t - \eta g_k$$

$$w_{t+1} \leftarrow \sum_{k=1}^{K} \frac{n_k}{n} w_{t+1}^{k}$$

Step 4: Server returns updated data back to all DTbots. Every DTbot will train the current model using local data and take one step of gradient descent. Return the result back to the server. For example the Number bth (b ∈ B) DTbot:

$$b \in B$$

$$w \leftarrow w - \eta \nabla l(w;b)$$

IV. UROBT MODEL ANALYSIS

A. *DTbot Basic Function*

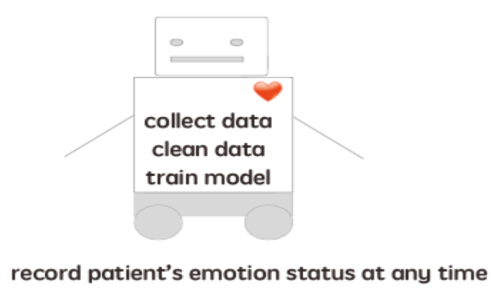

Fig. 6. Emotion Status Record Bot.

To help doctors, the hospital service robot is being turned into a depression treatment robot, each of which is responsible for several patients, classifies their faces, uses their na mes as a label, records their mood states and produces a graph of their mood fluctuations.

DTbot will play those music which patients love to help them relax their mood, whenever negative emotion gets detected. It may generate customized recommendation models for different patients, recommend specific music or activity for patients to become happy. In this way, a patient's state of illness can be aware and relieved before doctors can notice, because doctors always have lots of patients to pay attention to.

Sometimes, patients are willing to control their speaking tone and face expression in order to hide their real emotion. They are trying to convince doctors that they already get cured, so that they can end their therapy. This may cause very bad results. DTbot can compare the sentiment analysis result of patients' conversion and face expression to identify if they are real cured, or they are trying to hide something. Even if patients can get positive results through language sentiment analysis, they can not get through micro expression analysis. Micro expression is a very fast activity and very minor. people usually find it hard to control it. So, if we find there are differences between two analyses, we can state that this patient is hiding the real illness status, and this patient wants to give up, which is the one who should get a warning to the doctor.

B. Privacy Information Protection

In addition, through federated learning, doctors do not have to know the specific content of patients' conversation and activity videos. DTbots will upload the parameters which are trained locally to the server for model training, and send the final report to doctors. It is very important for a patient to know that their privacy gets well protected. Patients will behave more relaxed and this can be beneficial for their health. For example, some patients have their own way to relax or relieve their feelings, like painting and singing. However, they do not want others to hear their song or paint in case they may get mocked. If they find that this will be supervised by others, they will try not to do those activities, which cause their illness to become worse. Federated learning not only improved the learning ability of every RTBot, but also protected patients' privacy.

C. Unbalanced Data

Every patient has different habits, some one may talk much, some may like to keep silent. In other cases, some people like to have various facial expressions, the others are not. In addition, data will also change according to their illness status. Federated learning solved this problem by Federated averaging algorithm, which the server will take a weighted average of the resulting robots.

V. Conclusion

This paper remodified the hospital service robot to a Medical robot which can help cure depression patients. The main function of this robot includes the following. First, the voice sensor was used to analyze whether the patient's emotions were positive or negative while talking to the patient, which is implemented by using machine learning sentiment analysis approach. The patient's condition was determined by recording the patient's daily mood changes. Second, The video sensor was used to observe patients chatting micro-expressions. Use machine learning methods for micro-expression recognition to determine the patient's true feelings. Third, By comparing the patient's verbal emotions and micro-expression emotions to determine whether the patient is healing or not. The use of Federated learning resolved the problem of datas privacy, imbalance and real-time requirement.

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