

Hiding Information in Big Data based on Deep Learning

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Abstract: The current approach of information hiding based on deep learning model can not directly use the original data as carriers, which means the approach can not make use of the existing data in big data to hiding information. We proposed a novel method of information hiding in big data based on deep learning. Our method uses the existing data in big data as carriers and uses deep learning models to hide and extract secret messages in big data. The data amount of big data is unlimited and thus the data amount of secret messages hid in big data can also be unlimited. Before opponents want to extract secret messages from carriers, they need to find the carriers, however finding out the carriers from big data is just like finding out a box from the sea. Deep learning models are well known as deep black boxes in which the process from the input to the output is very complex, and thus the deep learning model for information hiding is almost impossible for opponents to reconstruct. The results also show that our method can hide secret messages safely, conveniently, quickly and with no limitation on the data amount.

Keywords: information hiding, big data, deep learning

1. Introduction

Deep learning has been used in many applications including disease treatment[1], resource management[2] and so on. Big data and cloud data bring many new challenges to many fields[3], especially to information security[4,5].

Information hiding is a way to hide confidential information in a large amount of information and not to let the opponent find it. The data amount of the carrier is limited in the existing technology of information hiding, which means the data amount of secret message is limited for it is impossible to hide more data amount of secret message than the data amount of the carrier. If we make use of the data in big data as carriers, we can not only solve this problem, but also can make information hiding more security, for before opponents want to extract secret messages from carriers, they need to find the carriers, however finding out the carriers from big data is just like finding out a box from the sea.

The algorithm for information hiding is as important as the carrier. Deep learning is equivalent to a complex algorithm that cannot be explained explicitly. Deep learning models are well known as deep black boxes in which the process from the input to the output is very complex. If the deep learning model is used for information hiding, it may achieve unexpected results. Deep learning has been used to detect image steganography in some researches [6-10], in which the deep learning model is used to determine whether or not an image is a steganographic image and can not be used to hide information. Deep learning has also been used to hide information in few researches.

In the first existing method of hiding information based on deep learning, the deep learning model is used to encode the cover carrier and secret message into a stego carrier in the process of hiding information and decode the secret message from the stego carrier in the process of extracting information. If the cover carrier is the data stored in big data, the data has to be modified to the stego carrier, which will destroy the data in big data, or the stego carrier has to be insert into big data as new data, which can not make use of the existing data in big data and will waste storage resources. In the second existing method of hiding information based on deep learning, the deep learning model generates a cover carrier into which the secret message will be inserted to form the stego carrier, and thus the generated carriers are not the data in big data and will waste storage resources. In the third existing method of hiding information based on deep learning, the deep learning model uses the secret message to generate the stego carrier from which the secret message can be extracted[11]. The stego carrier is not the existing data in big data and thus has to be inserted into big data, which will waste storage resources. There the existing methods are not suitable for hiding information in big data for not using the data in big data as the carrier.

In our method, the original carrier and secret message are used as the input and expected output to train the deep learning model, the original carrier is inputted into the trained deep learning model to obtain the output result which is usually close to and has a little difference with the secret message, and then the original carrier and little difference can be used to recover the secret message by inputting the original carrier into the deep learning model to obtain the output result which can be used to recover the secret message. Our method can make use of the existing data in big data as the carrier and recover the secret message from the carrier based on deep learning, and thus does not need to modify the data in big data or insert new data into big data.

There are some researches on information security in big data[12], however there is no existing research on hiding information in big data except a related research about hiding the secret message in a webpage that contains all the information to describe the secret message. However, the related research can only be used to hide text messages, cannot be used to hide other types of messages such as images, audios and videos, and when the secret message is larger than a web page, it is impossible to find a webpage that contains all the information to describe the secret message. What is more, the hiding algorithm of the related research is just a mapping between the text of the secret message and the text of the web page, so the secret message is easily extracted from the web page. Our method is based on big data which can hide various types of secret messages with no limit on the data amount, and based on deep learning which can make the secret message very difficult to extract.

Compared with the existing methods, our method of information hiding in big data based on deep learning has three advantages. Firstly, the data in big data will not be destroyed; secondly, no more storage space is occupied; thirdly, the carrier is difficult to find by the opponent for the carrier is the existing data in big data, and if the carrier can not be found, the secret information is certainly impossible to be found; fourthly, the secret message with an infinite data amount can be hid for the carrier are from big data; finally, the deep learning model is very complicated and difficult to explain, so the hiding algorithm based on deep learning is hard to break by the opponent.

The main contributions of this paper includes:

(1) The data in big data is used as the carrier for information hiding, which makes the carrier almost impossible to find by the opponent, and also saves space for storing the carrier.

(2) The training and testing process of deep learning model are used as the algorithm of hiding and extracting process, which makes the secret message almost impossible to be recovered for the extreme complexity of deep learning model.

(3) Our method is unbreakable when the sender and receiver share the deep learning model not through network.

The rest of the paper is organized as follows. Section 2 describes methodology. Then Section 3 presents the results and discussion. Finally, we conclude this paper in Section 4.

2. Methodology

2.1 Basic method of information hiding in big data based on deep learning

As shown in Figure 1, the method of hiding information is used in conjunction with the method of extracting information.

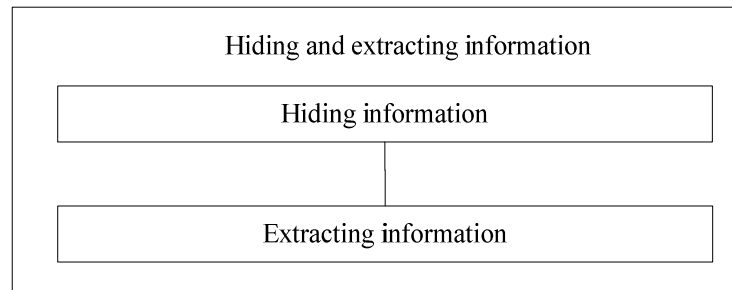


Figure. 1 Hiding and extracting information .

(1)Hiding information in big data based on deep learning

As shown in Figure 2, the process of hiding information in big data based on deep learning includes accepting the secret message, selecting the cover carrier, training the deep learning model, generating the stego carrier, generating the secret difference, hiding information multiple times, generating the authorization and verification information, and transmitting the authorization and verification information.

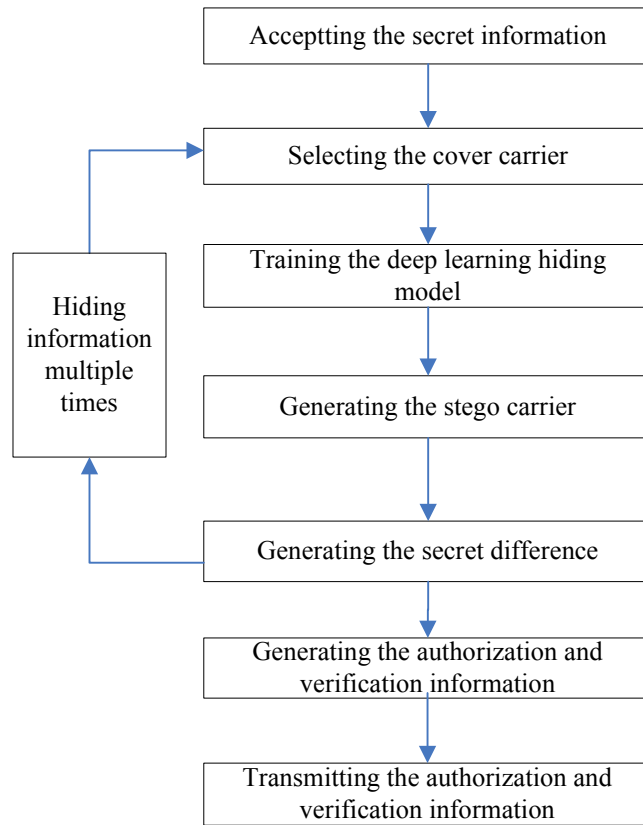


Figure.2 Hiding information .

The secret message inputted by the sender is accepted. The secret message refers to the information that the sender needs to hide, which can be uploaded by the sender through a browser, a client or the like. For example, the secret message contains 100 sentences. The format of the secret message can be in various formats such as text, audio and video.

The data in big data is selected as a cover carrier, and the location of the data in big data is obtained as the secret location. The carrier is selected according to the secret message or a preset rule such as selecting a consecutive block whose size is K from an inactive file in big data. If the cover carrier is consecutive, the secret location includes the start and end positions of the cover carrier; if the cover carrier is inconsecutive, the secret location includes multiple sets of start and end positions of consecutive data segments.

The data with the same type of the cover carrier and the message with the same type of the secret message are used as the input and expected output to train the deep learning model for information hiding, and the trained deep learning model is called the deep learning hiding model. The deep learning model can be CNN ,RNN and so on. The deep learning model is a kind of artificial neural network with little difference between the expected output and the actual output after training. If the computing ability is sufficient, the deep learning model is preferred, but if the computing ability is not enough, the traditional artificial neural network such as BP neural network can also be used instead of the deep learning model in our method. If the trained deep learning hiding model has existed, the model can be used directly.

The cover carrier in big data is inputted into the deep learning hiding model, and the output of the deep learning hiding model is used as the stego carrier. Since the deep learning hiding model has been trained by the data with the same type of the secret message as the expected output, when the cover carrier is input, the output of the deep learning hiding model has certainly the same type of the secret message.

The difference between the secret message and the stego carrier is computed and taken as the secret difference. The stego carrier has the same type of the secret message, and thus the stego carrier can be compared with the secret message. The formula for computing the secret difference is the secret difference = f (the secret message, the stego carrier), where f is a function for computing the difference, and if the secret message and stego carrier are both numbers, the formula can be simplified as the secret difference = secret message - the stego carrier.

The above processes can be executed multiple times. Multiple cover carriers and secret locations are obtained, and multiple deep learning hiding models are trained by using the input data with the same type of the cover carriers and the expected output data with the same type of the secret message. The differences between the secret message and the stego carriers are computed to obtain multiple secret differences.

The authorization information includes at least one set of secret difference, secret location, and parameters of the deep learning hiding model. The parameters of the deep learning hiding model include the type of neural network, number of layers, number of nodes per layer, weight of each connection between nodes in each layer, and so on. If the secret location is sent to the receiver, the receiver can obtain the cover carrier from the secret location in big data. If the deep learning hiding model is sent to the receiver, the receiver can input the cover carrier into the deep learning hiding model to compute out the stego carrier. If the secret difference is sent to the receiver, the user can synthesize the secret message according to the stego carrier and the secret difference. The secret difference, secret location, and deep learning hiding model are indispensable, and the receiver is impossible to extract the secret message without any one of them.

The partial data or the attribute information of the secret message is taken as the verification information and sent to the receiver. For example, the data in the last m bytes of the secret message or the number of bytes of the secret message is used as the verification information. The receiver can verify whether or not the extracted secret message is consistent with the verification information, which is very necessary for the cover carrier in big data may change which will lead to the extracted secret message is wrong. When there are multiple sets of authorization information, the secret message consistent with the verification information can be selected from the multiple extracted secret messages.

The authorization and verification information are sent to the receiver.

(2) Extracting information in big data based on deep learning

As shown in Figure 3, the process of extracting information in big data based on deep learning includes accepting the authorization information, extracting the cover carrier, generating the stego carrier, generating the secret message, extracting information multiple times, synthesizing the secret message, and transmitting the secret message.

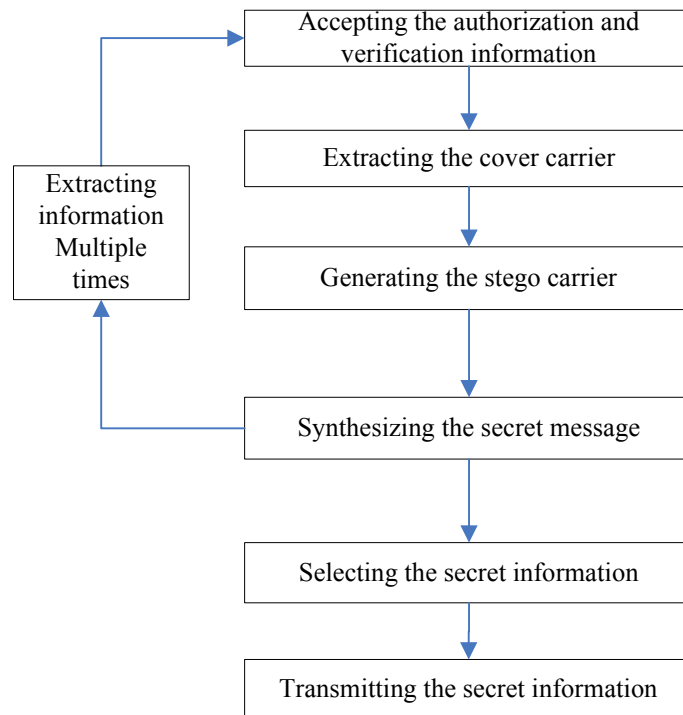


Figure. 3 Extracting information.

The verification information and at least one set of the authorization information including the secret difference, secret location, and parameters of the deep learning hiding model inputted by the receiver are accepted. The deep learning hiding model is automatically generated and configured according to the parameters.

The cover carrier is obtained from big data according to the secret location. The cover carrier is inputted into the deep learning hiding model, and the output is used as the stego carrier. The secret message is synthesized according to the stego carrier and the secret difference. When recovering the secret message, the secret difference and the stego carrier are substituted into the formula the secret difference = F (secret message, the stego carrier) to calculate the secret message. If the secret difference and the stego carrier are both numbers, the formula can be simplified as the secret message = the stego carrier + the secret difference.

The multiple sets of authorization information may be used to obtain multiple secret messages by executing the above process multiple times. The secret message that is consistent with the verification information is

selected from the multiple secret messages and transmitted to the receiver. The receiver can also view or download online through a browser, a client or the like.

2.2 Parallel method of information hiding in big data based on deep learning

Parallel hiding and extracting is very necessary for the secret message which contains a very large amount of data, which can greatly speed up the process of hiding and extracting information

(1) Hiding information in big data based on deep learning in parallel

As shown in Figure 4, the process of hiding information in parallel is based on the process of hiding shown in Figure 2. Accepting the secret message further includes dividing the secret message; selecting the cover carrier further includes selecting multiple cover carriers; training the deep learning hiding model further includes training deep learning hiding models; generating the stego carrier further includes generating multiple stego carriers; generating the secret difference further includes generating multiple secret differences; generating the authorization and verification information further includes generating multiple sets of authorization and verification information, and transmitting the authorization and verification information further includes transmitting multiple sets of authorization and verification information

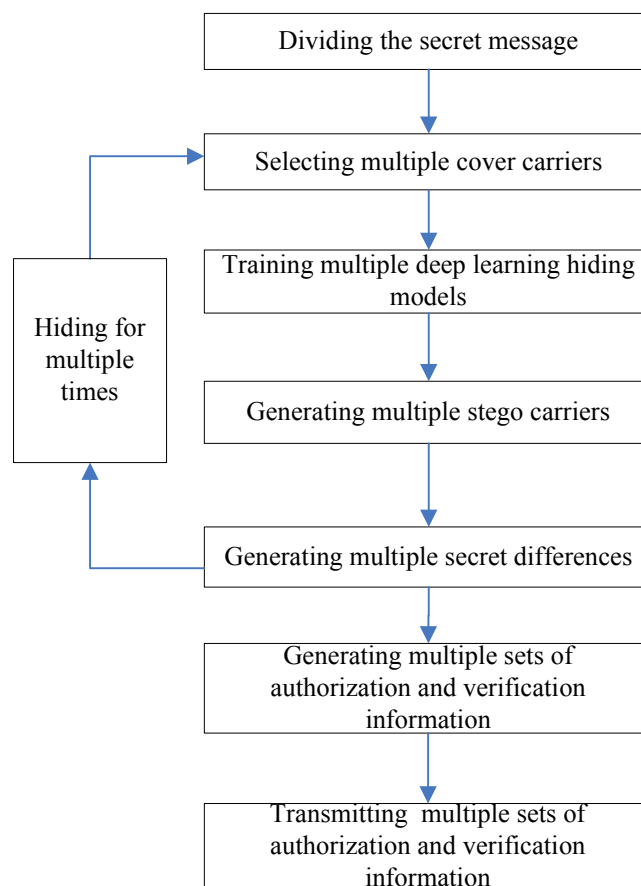


Figure. 4 Hiding information in parallel.

The secret message is split into P secret sub-messages, where $P \geq 1$, and the position number of each secret sub-messages in the secret message is called as the secret number. For example, there are 100 sentences in the secret message and each sentence is divided into 100 strings. The position number of a string is 004006, which means the string is the sixth string in the fourth sentence. Hiding secret message after segmentation can further improve the security of information hiding, for the opponent can not recover the whole secret message even if he recovers parts of the secret message.

P cover carriers are selected from big data, and one-to-one correspondences between the P cover carriers and the P secret sub-messages are erected. The P cover carriers are located at P locations which can be storage locations or paths or index numbers. The locations are obtained as the secret locations.

The data with the same type of each of the cover carriers and the data with the same type of its corresponding secret submessage are used as the input and expected output to train its corresponding deep learning hiding model, and multiple deep learning hiding model are obtained. If the trained deep learning hiding

models has existed, then the model can be used directly. Each of the cover carriers is inputted into its corresponding deep learning hiding model, and the output is obtained as its corresponding stego carrier.

There are one-to-one correspondences between the secret sub-messages and the stego carriers, for there are one-to-one correspondences between the cover carriers and the secret sub-messages, and there are one-to-one correspondences between the cover carriers and the stego carriers. The difference between each of the secret sub-messages and its corresponding stego carrier is taken as its corresponding secret difference.

The multiple sets of secret location, secret numbers, secret difference, and deep learning hiding model are transmitted to the receiver, which can be used to generate the multiple secret sub-messages during the process of extracting information.

(2) Extracting information in big data based on deep learning in parallel

As shown in Figure 5, the process of extracting information in parallel is based on the process of extracting shown in Figure 3. Accepting the authorization and verification information further includes accepting multiple sets of authorization and verification information; extracting the cover carrier further includes extracting multiple cover carriers; and generating the stego carrier further includes generating multiple stego carriers; synthesizing the secret message further includes synthesizing multiple secret sub-messages and synthesizing the secret message.

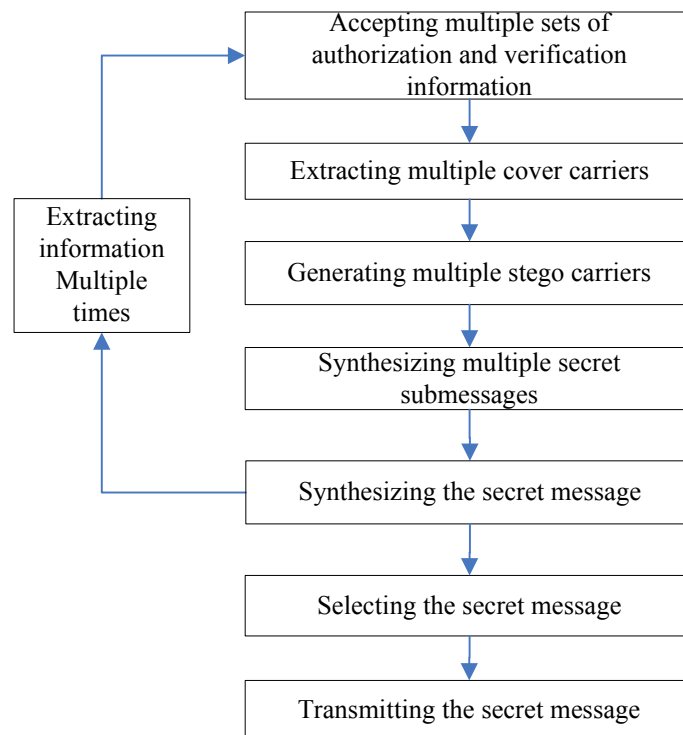


Figure. 5 Extracting information in parallel.

Multiple sets of secret location, secret numbers, secret difference, and deep learning hiding model inputted by the receiver are accepted. Each of the cover carrier from big data is located and obtained through the secret locations. Each of the cover carriers is inputted into its corresponding deep learning hiding model, and the output is taken as its corresponding stego carrier. Each of the secret sub-messages is synthesized according to its corresponding stego carrier and secret difference. The secret message is synthesized according to the secret sub-messages and the secret numbers.

2.3 Unbreakable method of information hiding in big data based on deep learning

The only approach to break our method is that the opponent obtains the authorization information and knows how to use our method to recover the secret message based on the authorization information. If not all parts of the authorization information are obtained by the opponent, the opponent is impossible to recover the secret message for any part of the authorization information is indispensable for recovering the secret message. Different parts of the authorization information can be sent to the receiver through different channels at different times, which can greatly increases the difficulty of all parts of the authorization information being obtained by the opponent.

In the process of hiding information, the secret difference can not be generated without the secret message, the secret location is not dependent on the secret message, and the deep learning hiding model is not dependent on the content of the secret message but the type of the secret message. If the type of the secret message is known ahead of time, the deep learning hiding model can be generated ahead of time, and the deep learning hiding model can be used for hiding all kinds of secret messages with the type. Therefore, the sender and receiver can share the secret location or the deep learning hiding model ahead of time not through network but other approaches such as copy or express delivery. Then the sender and receiver can use the secret location or the deep learning hiding model to hide and extract the secret message. Since only the secret difference are transmitted on the network between the sender and the receiver, even if the opponent intercepts the secret difference, the secret message cannot be recovered at all without the secret location or the deep learning hiding model, and thus the method is unbreakable for information hiding.

Even if the secret location or the deep learning hiding model have to be shared between the sender and the receiver through network, there are two methods to reduce the risk of network transmission being intercepted. The first method is that the secret location or the deep learning hiding model is transmitted long before the secret difference is transmitted. If the interval is enough long, the opponent will think the secret location or the deep learning hiding model has no relation with the secret difference. The second method is that the transmission of different parts of the authorization information in different directions. For example, the receiver sends the deep learning hiding model and secret location to the sender, and then the sender send the secret difference to the receiver. The two methods can extremely reduce the possibility of the opponent to intercept and use together the different parts of the authorization information.

3. Results and discussions

3.1 Experiments

The computer we used for hiding and extracting information has a 3.80GHZ CPU and a 4G memory, and the trained deep learning hiding model we used can accept an input image and output a text. The process of hiding information with the trained deep learning hiding model takes only about 3 seconds, and the process of extracting information also takes only about 3 seconds.



Figure. 6 Image in big data from the Internet.

Experiment 1: The sender Alice needs to send "Knife" as the secret message to the receiver Bob.

The process of hiding information: The secret message "Knife" is inputted by Alice, and an image in big data from the Internet is randomly downloaded. The image is shown in Figure 6, and the location of the image in big data is the url <https://origin-thumbs.bigstockphoto.com/zh/image-4671121/stock-vector-树>. A trained deep learning model which can recognize more than one thousand objects is obtained as the deep learning hiding model. The image is inputted into the deep learning hiding model, and the output is "pot, flowerpot" with a score of 0.74342. From the output we can see that the recognition result is actually wrong, but it does not affect the effect of the experiment. By converting Ascii text to decimal, the output "pot, flowerpot" is converted to the array [112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116] and the secret message is converted into the array [107, 110, 105, 102, 101]. The lengths of the two arrays are different, and thus in order to comparing the difference, the array [112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116] is converted to the array [112, 111, 116, 44, 32] with the same length of the array of the secret message. The difference between the two arrays is calculated to obtain the array of the secret difference [-5, -1, -11, 58, 69]. The location of the image in big data, the parameters of the deep learning hiding model, and the array of the secret difference are sent to Bob through different channels.

The process of extracting information: Bob receives the location of the image in big data, the parameters of the deep learning hiding model and the array of the secret difference. The deep learning hiding model is reconstructed according to the parameters. The image is downloaded from the location and inputted into the deep learning hiding model to compute the output. The output is "pot, flowerpot" with a score of 0.74342. The output "pot, flowerpot" is converted into the array [112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116] which needs to be converted to the array [112, 111, 116, 44, 32] with the same length of the array of the secret difference. The array of the output is added to the array of secret difference to get the array [107, 110, 105, 102, 101] which is converted into the secret message "Knife" by decoding decimal number to ascii text.

Experiment 2: The sender Alice needs to send the secret message "We will meet at the place we met last week at 12 o'clock tomorrow morning." to the receiver Bob.

The process of hiding information: the secret message "We will meet at the place we met last week at 12 o'clock tomorrow morning " is inputted by Alice. The image and the deep learning hiding model is same as the first experiment. The output of the deep learning hiding model is converted to the array [112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116], and the secret message is converted into the array [87, 101, 32, 119, 105, 108, 108, 32, 109, 101, 101, 116, 32, 97, 116, 32, 116, 104, 101, 32, 112, 108, 97, 99, 101, 32, 119, 101, 32, 109, 101, 116, 32, 108, 97, 115, 116, 32, 119, 101, 101, 107, 32, 97, 116, 32, 49, 50, 32, 111, 39, 99, 108, 111, 99, 107, 32, 116, 111, 109, 111, 114, 114, 111, 119, 32, 109, 111, 114, 110, 105, 110, 103, 46]. In order to comparing the difference, the array [112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116] is converted to the array [112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44] with the same length of the array of the secret message. The difference between the elements of two arrays is calculated to get the difference array [-25, -10, -84, 75, 73, 6, 0, -79, -10, 0, -13, 4, -79, -19, 4, -79, 0, 60, 69, -70, 4, -3, -22, -2, -13, -80, 8, -15, -80, -2, -15, 72, 0, 6, -11, 4, -3, -69, 5, -11, -10, -9, -80, -14, 0, -12, 17, -52, -76, 0, -80, -2, -6, -1, -12, -9, -80, 5, -5, 65, 79, 12, 6, 0, 0, -69, -5, -1, 3, -6, -7, -1, -13, 2]. The location of the image in big data, the parameters of the deep learning hiding model, and the array of the secret difference are sent to Bob through different channels.

The process of extracting information: Bob receives the location of the image in big data, the parameters of the deep learning hiding model, and the array of secret difference. The image is downloaded from the location in big data, and inputted into the deep learning hiding model to compute the output. The output is "pot, flowerpot" with a score of 0.74342. The output is converted into the array [112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116] which needs to be converted to the array [112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44, 32, 102, 108, 111, 119, 101, 114, 112, 111, 116, 112, 111, 116, 44] with the same length of the array of the secret difference. The array of the output is added to the array of secret difference to get the array [87, 101, 32, 119, 105, 108, 108, 32, 109, 101, 101, 116, 32, 97, 116, 32, 116, 104, 101, 32, 112, 108, 97, 99, 101, 32, 119, 101, 32, 109, 101, 116, 32, 108, 97, 115, 116, 32, 119, 101, 101, 107, 32, 97, 116, 32, 49, 50, 32, 111, 39, 99, 108, 111, 99, 107, 32, 116, 111, 109, 111, 114, 114, 111, 119, 32, 109, 111, 114, 110, 105, 110, 103, 46] which is converted into the secret message " We will meet at the place we met last week at 12 o'clock tomorrow morning." by decoding decimal number to ascii text .

3.2 Results

Although the secret message in our experiments is text, our method can also be used to hide the secret message with the types of image, video, audio, and so on by changing the output type of the deep learning hiding model.

In the two experiments, even if the opponent obtains the image in big data, when he see a tree in the image, so it is almost impossible for him to think that the secret message may be "Knife" or "We will meet at the place we met last week at 12 O'clock tomorrow morning"; even if the opponent obtains the parameters of the deep learning hiding model, from which he knows the object types which the model can recognize, he does not know which type is related with the secret message and almost impossible to guess the type for there are more than one thousand types in the parameters.

The secret location and the parameters of deep learning hiding model seems to have no relationship with the secret message, so even if the opponent intercepts the authorization information, the secret message could not be recovered without knowing the role of each part of the authorization information. The cover carrier is selected from big data, so it is very difficult for the opponent to find the cover carrier for big data is too large. Even if the cover carrier is found, the opponent can not get the stego carrier without the deep learning hiding model. Further, even if the stego carrier is obtained, the secret message cannot be recovered without the secret difference. The three insurmountable thresholds make our method extremely hard to break, and when the secret location or the deep learning hiding model is shared not through network before information hiding, our method is impossible to break by the opponent.

3.3 Discussion

Big data is often stored in cloud with many users, which means that it is difficult to ensure the data in big data does not change. If the cover carrier changes in big data, the stego carrier outputted by the deep learning hiding model in the process of extracting information will be not consistent with the stego carrier in process of hiding information, and finally the recovered secret message will be wrong. Our method makes use of multiple cover carriers to overcome this problem. As long as one of the cover carriers does not change, the secret

message can always be recovered correctly with the help of the verification information, which can greatly improve the robustness of our method.

If the data amount of the secret message is very large, the secret message can be divided into multiple secret sub-messages in our method. Since the data amount of big data is very large, the different carriers corresponding to the different secret sub-messages can be selected. Therefore, the data amount of the secret message can be unlimited.

Moreover, different channels may be used for transmitting the different parts of the authorization information, and the authorization information can be transmitted at different times. For example, the secret difference is sent to the receiver through the first network path, the secret location through the second network path, and the deep learning hiding model through the third network path, which can make the opponent harder to break our method, for the opponent can not recover the secret message even if parts of the authorization information are intercepted. Our method becomes unbreakable when the sender and the receiver share the secret location or the deep learning hiding model not through network before information hiding.

4. Conclusion

We proposed a novel method of information hiding in big data based on deep learning. Our method uses the existing data in big data as the carrier, and uses the deep learning model as the function of hiding and extracting information. In the process of hiding information, the cover carrier in big data is inputted into the deep learning hiding model, the output of the model is used as the stego carrier, and the difference between the stego carrier and the secret message is taken as the secret difference. In the process of extracting information, the cover carrier in big data is inputted into the deep learning hiding model, the output of the model is used as the stego carrier, and the secret message is synthesized according to the stego carrier and the secret difference. The results also show that our method can hide secret messages safely, conveniently, quickly and with no limitation on the data amount. When the secret location or the deep learning hiding model is shared not through network before information hiding, our method is unbreakable. The deep learning model in our method can also be replaced by other functions such as BP artificial neural network and big data in our method can also be replaced by other data sources such as Internet data and IOT data, which means that our method opens a new door for information hiding.

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