Poolice - A stool recognition neural network mobile application for colorectal cancer detection

Field of the invention

This invention relates to deep learning methods of detecting cancer. Specifically, the invention describes a mobile application system to detect the presence of blood in one's stool (which indicates a possible risk of colorectal cancer) from an image of it.

Background

Colorectal cancer is the most common cancer and one of the top killer cancers in Singapore. According to the Singapore Cancer Registry, about 1500 patients are diagnosed with colorectal cancer annually and around 650 of them die from it each year. Worldwide, colorectal cancer is the third most common cancer and there were over 1.8 million new cases in 2018.

Despite being a deadly disease, the earlier colorectal cancer is detected, the more likely it can be treated successfully. Colorectal cancer can be detected through a number of screening tests.

One such test is colonoscopy, to observe for the presence of polyps, which are abnormal tissue growths which may turn cancerous. As colonoscopy is an invasive procedure carried out by a medical professional (a hospital visit is required) and costs are payable, a person may not opt for this screening unless necessary.

Another test is the faecal occult blood test (FOBT), a laboratory test that checks stool samples for blood, which is a common symptom of colorectal cancer. However, the FOBT has several limitations. It is tedious and unpleasant as one has to manually collect 2 stool samples, the waiting period for results takes around 2 weeks and costs are involved.

Therefore, there is a need for a convenient, fast and cost-free alternative to the FOBT to help people detect blood in their stool (which is a symptom of colorectal cancer), so they can seek medical attention earlier and increase their chances of survival.

Summary of the Invention

The inventors developed a mobile application system, “Poolice”, built on a stool recognition neural network with an accuracy of 94%, to detect the presence of blood in one’s stool (which indicates a possible risk of colorectal cancer) based on an image of it. This is a new classification task and there are currently no suitable datasets. The inventors compiled a 1610-image dataset consisting of three classes (i.e bloody stool, normal stool and no stool) and trained the model with the dataset as well as synthetic images generated by a generative adversarial network (GAN), more specifically a StyleGAN2, to improve classifier accuracy.

The inventors trained a StyleGAN2 network to generate abnormal stool, normal stool, and no stool images to enlarge the dataset to improve the performance of the stool recognition neural network. GANs are deep learning algorithms that generate images with many realistic characteristics and look authentic to the human observer. They consist of 2 neural networks contesting with each other in a zero-sum game framework – a generator which generates images similar to the training input from a latent space (usually Gaussian distribution), and a discriminator which discriminates between real images and synthetic images produced by the generator. During training, the generator tries to outsmart the discriminator by generating increasingly convincing fakes, while the discriminator learns to better identify the real data from the fakes. Nash equilibrium is reached when the generator generates perfect fakes, and the discriminator is left to guess at 50% confidence if the generator output is real or fake.

The StyleGAN2 was trained on the 1610-image dataset using differentiable augmentation, a special type of image augmentation that enables GANs to generate a wide variety of realistic images from a small training set. Differentiable augmentation techniques (translation, cut-out augmentation and colour jittering) were applied to both real and generated images before passing them to the GAN discriminator. In the end, the StyleGAN2 generated realistic images of the 3 classes which had a high fidelity to the dataset.

The stool recognition neural network was then developed and trained on the 1610-image dataset as well as 200 additional synthetic images per class generated by the StyleGAN2 on-the-fly. The model was evaluated on a fixed test set of 160 images (60 abnormal stool, 60 normal stool, 40 no stool) set aside from the 1610-image dataset and it achieved a high test accuracy of 94%.

To ensure that the stool recognition neural network was learning the regions with stool in the image, Gradient-weighted Class Activation Mapping (Grad-CAM) was applied to the test images. The average Grad-CAM heatmap of each class was derived by averaging the heatmaps of all processed images in each class. In the average heatmaps, yellow high-intensity regions were concentrated at the centre of the image where the stool was located. This proves that the stool recognition neural network was focusing on the features of the stool for the classification task and not other features like the background.

Finally, the stool recognition neural network was deployed to the Poolice mobile application using TensorflowLite. Poolice was developed with an easy-to-use interface and a built-in camera function, achieving the original goal of assisting potential colorectal cancer patients in assessing if they have signs of symptoms. To use the application, users simply take a photo of their stool and obtain an instantaneous diagnosis on their risk of colorectal cancer. The stool recognition neural network deployed in the application will make a prediction based on the photo of the user's stool and display the confidence results for each image class.

Brief Description of the Drawings

FIG. 1 provides a schematic illustration of how the Poolice mobile application system works.

FIG. 2 shows the breakdown of the 1610-image dataset and non-limiting image examples.

FIG. 3 provides non-limiting examples of synthetic images generated by the StyleGAN2 using differentiable augmentation for each image class.

FIG. 4 provides a schematic illustration of the stool recognition training pipeline.

FIG. 5 illustrates the average Grad-CAM heatmaps of each image class.

FIG. 6 provides screenshots of the Poolice mobile application.

Claims:

1. A mobile application system to detect blood in one's stool (which indicates a possible risk of colorectal cancer) from an image of it, comprising:
    a. A user interface for one to take a photo of his/her stool sample.
    b. A trained stool recognition neural network (deep learning algorithm) deployed in the mobile application that makes a prediction on the image.
    c. An output screen which displays the classification results and a message to the user.

2. The system of claim 1, wherein all layers of the stool recognition neural network are trained based on the training images comprising 3 image classes.

3. The system of claims 1-2, wherein the 3 image classes include abnormal stool (stool with blood), normal stool (stool without blood) and no stool (empty toilet bowls).

4. The system of claims 1-3, wherein all layers of the stool recognition neural network are trained based on a 1610-image dataset of real images of the 3 image classes.

5. The system of claims 1-4, wherein all layers of the stool recognition neural network are also trained by a method of generating synthetic images using a generative adversarial network (GAN) and adding the synthetic images to the stool recognition neural network's training set in order to improve classification accuracy.

6. The method of claims 1-5, wherein the said GAN is a StyleGAN2 network.

7. The method of claims 1-6, wherein the StyleGAN2 network is trained with the 1610 real image dataset.

8. The method of claims 1-7, wherein the StyleGAN2 network trained with the 1610 real image dataset was trained using differentiable augmentation.

9. The system of claims 1-8, wherein the stool recognition neural network is a convolutional neural network.

10. The system of claims 1-9, wherein the training set for the stool recognition neural network comprises the 1610 real image dataset and additional synthetic images generated on-the-fly by the GAN.

11. The system of claims 1-10, wherein data augmentation is used for the stool recognition neural network training process in order to boost classification accuracy.

12. The system of claims 1-11, wherein the stool recognition neural network generates confidence values for each of the 3 image classes.

13. The system of claims 1-12, wherein the stool recognition neural network achieved a classification accuracy of 94%.

14. The system of claims 1-13, wherein the mobile application's output screen displays the confidence levels of the 3 image classes and a message to the user based on the image class with the highest confidence level.

15. The system of claims 1-14, wherein the output screen's message to the user can either be "Abnormal Stool" for the abnormal stool class, "Normal Stool" for the normal stool class and "No Stool Detected" for the no stool class.