A SAFETY MOBILE APP FOR EXERCISE EQUIPMENT SAFETY USING FACIAL RECOGNITION AND AI TECHNOLOGY

Jingyi Liu [1], Jonathan Sahagun [2]

[1] Tarbut V'Torah Community Day School, 5200 Bonita Canyon Dr, Irvine, CA 92603
[2] Computer Science Department, California State Polytechnic University, Pomona, CA 91768

ABSTRACT

Exercise has become an increasingly popular trend, but injuries caused by overexertion remain a concern. To address this issue, we developed an AI-powered application that utilizes face detection to prevent users from overexercising. Our application integrates Vertex AI and Bluetooth Low Energy (BLE) technology to enhance connectivity and performance. During development, we encountered challenges in detecting user fatigue and establishing a reliable connection between the application and the treadmill. To validate our system, we conducted experiments to assess the accuracy of AI face detection across different users. Our findings indicate that the AI successfully detects faces regardless of age; however, it struggles to recognize individuals with darker skin tones due to limited training data. Compared to other methods, our application offers a proactive approach to injury prevention during exercise. Additionally, it includes a mechanism to forcibly stop the user if they ignore fatigue warnings, ensuring a safer workout experience.

KEYWORDS

AI, Facial Recognition, Fitness Equipment, Exercise Safety

1. INTRODUCTION

In modern society, exercise has become an essential part of people's lives. This is an activity that all age ranges people are participating in. Exercising should've been a great thing for society because everyone is protecting their health; however, with more people exercising, the injuries caused by fitness equipment also increased. In the United States, there are around 30 million teenagers and kids participating in sport, and each year, there are 3.5 million of them experiencing injuries due to exercise [1]. Among these, many injuries were caused by the over exercise on moving equipment, for example, the treadmill. Research shows that in an insurance company, a health analysis group has presented that there are 233 claims associated with treadmill injuries in 12 years, which is the top five of 20 different types of claims [2]. This shows how significant is the need of protecting users on treadmill exercise in our society. Not only does using a treadmill would cause injuries, just running too much would also cause muscles overstretched. Blair's group reported an experiment that they did, which was to let 438 men and women run 25 miles a week, and 24% among these 438 people reported injuries, showing that high running mileage are associated with the possibility of getting injured [3]. This injury problem would not be able to be solved by itself without human intervention. As time goes on in the future, fitness equipment similar to treadmills will get generally more provided, and the

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exercise population will also increase. Previous data shown, between 2000 and 2010, the American exercise population experienced a 10.7% increase [4]. As the population increases, the number of people that get injured would also increase as the time goes since there are always a variety of people starting to exercise. Among all the people exercising, there would be elders and people that have health issues, which would need extra protection during exercise. With the high proportion of safety problems, we want to propose an Application that can effectively protect users' safety from over exercising.

For the first method, the scholars want to incorporate more exercise before doing sport to prevent injuries during sport. This is a great solution except that the scholar neglected the possibility of injuries when warming up. Our Application could help improve this by using our Application when exercising to prevent injuries even before the sport. The second methodology that other scholars suggested is to create an exercise schedule. This would work in the long run for preventing the user from continuously exercising, but it has the shortcoming of ignoring the danger from everyday exercise. There is the possibility for the user overexercise in one day and cause injuries. Our Application could be used with an exercise schedule, so we can prevent both short term and long term danger from exercising. The last method is using similar tools like smart watches. It could detect the user's heart rate and record work load every second, but it has the limitation when trying to stop the user from overexercising. Smart watches do not have a forceable way to stop the user, whereas our Application could force the user to stop by stopping the treadmill after detecting tiredness.

The method we proposed is to create an Application that can use AI face recognition to determine if the user is tired or not, and if the user is tired for a set up of time, the Application would stop the treadmill in order to force the user to rest. This Application can solve our problem of injuries during exercise by preventing the user from over exercising. When the users overstretch themselves, they would show a face expression of pain or tiredness, and when this face expression has been shown for a long period of time, it becomes a signal for the Application to indicate that the user is tired and needs to stop exercise. Many injuries were caused by the user overexercising and hurting their muscles or ankles, and by preventing them from over-exercising, the Application can effectively prevent further injuries caused by it. This is a better solution than smart watch or wristband because AI can always check the user's face, but sometimes smart watch or wristband could get loose and wrongly track the user's heart beat, which may cause the treadmill to stop when it shouldn't. Furthermore, our Application can detect if the user is in the camera or not. If AI can't detect a user's face, it will immediately stop the treadmill in order to prevent further damage if the user fell off the treadmill. This is not something that a wristband or smart watch can do, because even if the user fell off the treadmill, their heart beat will not stop, and the smart watch wouldn't detect anything for the treadmill to stop. We can't be fully sure that the falling detect system would always work, but we can be sure that when some fall, their face would not appear in the camera where their face would appear when they're standing straight.

Both of the experiments we did had the same purpose of knowing what variety of people are available for our Application. Among these two experiments, we focused on the skin color and the age of the user. Can the AI detect tiredness on them? We set up the experiments in a similar way, let different people stand in front of the camera and use the camera to exercise. We want to see if AI can detect different user'stiredness, and is there a limitation for detecting it. The most significant finding for the first experiment is that we need to focus on how to let AI detect the facial expression of blacked people, and the second significant finding in our second experiment is that we know that age is not a problem when facing AI detection. The way how AI is trained and the picture they're facing greatly affect the results.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Adding a Cable

The connection between the Application and the treadmill is the first thing we should consider. When connecting from the Application to the treadmill, since there are multiple ways for connection, we need to decide whether we should use wire or wireless connection. We could use wire connection, but adding a cable can create numerous problems that affect the safety of the user when running on the treadmill. We could use bluetooth connection or bluetooth low energy detection depending on which system the treadmill uses. With wireless connection, the only thing a user needs to do is put their phone with the Application on the side of the treadmill and connect to it.

2.2. AI Face Detection

AI face detection is the main component of this Application. During the programming process, we need to find an usable AI system that could successfully determine the user's tiredness. We could use the AI face detection system that other people shared online, but many of them could not successfully detect face emotion. In addition, tiredness is a very subtle expression to determine. Many people made AI detect happiness, sadness, or anger, but not much can detect tiredness. Some could be used, as some people created a real time tiredness detector, but these are not public for us to use, and it was created with python that is different from our system [5]. Furthermore, many AI systems are programmed to give an answer no matter what they detected. They may say a tree or a rock is happy or sad. We could use an AI system like vertex AI by putting in pictures and asking them if the person is tired or not and let them answer in yes or no format. By this, we could take a picture of the user every 30 seconds, send it to vertex AI, and get an answer of both if the user is in the camera and if the user is tired or not.

2.3. Stop the Treadmill

The performance of the Application is greatly impacted by the criteria for the App to stop the treadmill. We could make the treadmill stop immediately as the AI detects tiredness on the user's face, but that would not be the best option because many times a user will show tiredness, but they are not over-stretching themselves. We could take a picture of the user every 5 seconds, and if in a certain amount of time the user is detected as tired, for instance, 30 seconds in a roll, the Application could send the signal to stop the treadmill. For detecting if the user is in the camera or not, we could make the treadmill stop immediately because we don’t know what would happen if the user fell off the treadmill, so stopping it immediately could be the best choice.

3. SOLUTION

Our Application has 3 major components: AI Face Detection, Information returned, and treadmill control. After the user connects the Application to the treadmill, the Application would automatically open the camera and start to detect the user's face expression. Users can use the Application or the treadmill to start and stop the treadmill. Once the treadmill starts, the AI system would start to detect the user's face expression every 30 seconds. When AI doesn’t detect tiredness, they would return phrases like “you’re doing great”, “keep on going!”, etc. When AI detects tiredness, they would return phrases like “you’re looking tired, recommend to stop”. The Application would record the 10 previous detection results, and if among these 10, more than half

of it is tired, then the Application would automatically stop the treadmill to prevent over exercising. After every exercise, the Application would record the start time of the exercise in the "exercise history" page.

For creating the Application, we incorporated vertex AI in our system. Each time when the Application takes a picture of the user, it will upload it to vertex AI and ask if the person in the picture is tired or not. The Application would let Vertex AI answer in yes or no format, so the Application would return the corresponding phrases based on AI's answer. We then type the code that's used to control the treadmill inside the Application, including the code for start and stop. When the Application saved more tired signals than neutral ones, the Application would send the stop code to the treadmill by bluetooth low energy connection to stop the treadmill. When stopping the treadmill, the treadmill will show the speed on the screen and constantly slow down to prevent the user to fall off the treadmill.

Figure 1. Overview of the solution

For AI Face detection, we used vertex AI in our system. This is for the purpose of determining if the user is tired or not, so the Application can know the user's status and stop the treadmill when necessary. For using vertex AI, the Application would need to use the internet, which means the user would need to stay in a place where it has signal when exercising. AI Face detection is one of the most important components regarding our Application because it is how the Application would function with knowing if the user is tired or not.

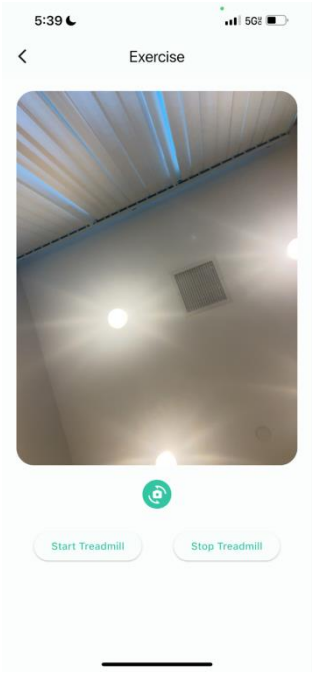

Figure 2. Screenshot of detect photo

```
class _State extends State{

  final Duration waitTime = const Duration(seconds: 30);

  bool isProcessing = false;

  String key = "AIzaSyB3KPq6yts06j12U8dUOr-G8ArZmVXwa4A";

  final model = GenerativeModel(
    model: 'gemini-1.5-flash-latest',
    apiKey: "AIzaSyB3KPq6yts06j12U8dUOr-G8ArZmVXwa4A",
  );

  final prompt = 'Does this person look tired, exhausted or over exerting from working out. Answer in a yes no format.';
```

```
Future<void> aiRequest(XFile file) async {

  // ByteData image_bytes = await rootBundle.load('lib/assets/b.jpg');
  Uint8List imageBytes = await file.readAsBytes();

  final content =[
    Content.multi([
      TextPart(prompt),
      DataPart('image/jpeg', imageBytes),
    ])
  ];
  // final content = [Content.text("How are you?")];
```

Figure 3. Screenshot of code 1

In the first screenshot, it shows that we set the time between every picture taken as 30 seconds. This is a timer that we would later call in our startStopTimer method, where we would call the timer and then stop the timer at the 30th second. Once we stop the timer, the Application would automatically press the invisible takePictureButton and then take the picture of the user. Then, we set up the vertex AI as the key with the latest picture as the model. We would then upload that picture to Vertex AI and then put in the prompt that's already written in the code as "final prompt =". In the second screenshot, it shows how the image file is uploaded to vertex AI. We first createa method called aiRequest with the XFiles, which is the file that we took. Then, we create a content that would ask the question to the Vertex AI with the prompt, which is the prompt we typed in the first screenshot. We also upload the latest picture that we took as imageBytes.

The second component of our Application is giving feedback based on if the user is tired or not. This is made for warning the user by saying they're tired and recommend them to stop exercising. For creating a feedback system, the user does not need to wait until the Application stops the treadmill. Instead, the user can stop the treadmill by themselves after being warned by the Application. This system is created based on the answer that Vertex AI gives back.

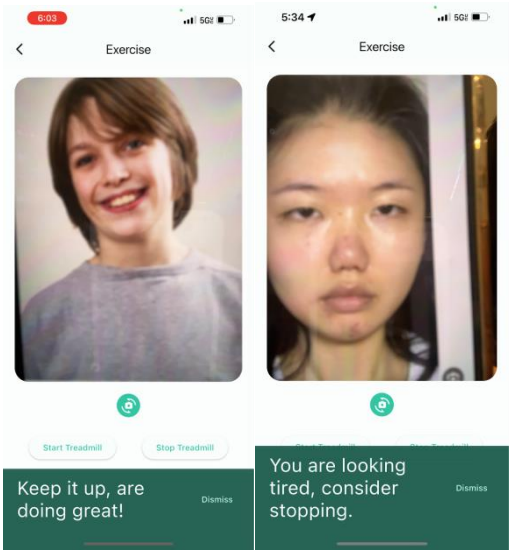

Figure 4. Screenshot of the facial expression

```
  final response = await model.generateContent(content);

  print(response.text);
  if(response.text!.toLowerCase().contains("yes")){
    showInSnackBar("You are looking tired, consider stopping.");
  }
  else{
    showInSnackBar("Keep it up, are doing great!");
  }
}
```

Figure 5. Screenshot of code 2

At first, we initiate the "response" to the answer that Vertex AI gave back after the Application asks if the person is tired or not in yes or no format. Then, we print out the response into texts so we can see if the answers contain a "yes" or "no". We wrote that if tis response, in all lower case, contains the word "yes", then we will show in the bar "You are looking tired…" because the Vertex AI is saying yes the person is tired. If the response does not contain a "yes", then that means the person is not tired. "else" command means all other cases except the one mentioned before, so if the answer does not contain a "yes", then the Application would default that the user is not tired. It will return the phrase "Keep it up…" in the snack bar. The phrase will show up every 30 seconds when the picture is taken by the Application so the user can update their status on time.

The ability to control a treadmill is a very important component for our system. This is the main purpose of our Application, which is to be able to stop the treadmill when the person is detected as tired. We used the command that the treadmill already established in their system to stop the treadmill.

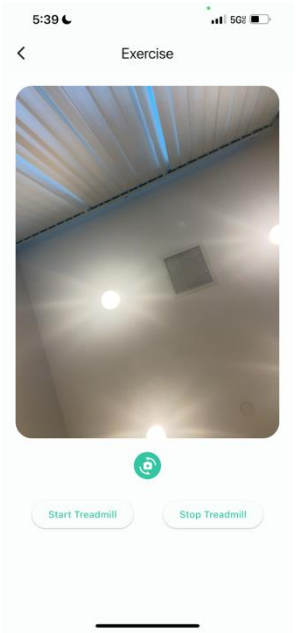

Figure 6. Screenshot of the detect photo

```
Future<void> startTreadmill() async {
  print("startTreadmill");
  String message = "AA080008AB";
  await writeToTreadmill(message);
}

Future<void> stopTreadmill() async {
  print("stopTreadmill");
  String message = "AA090009AB";
  await writeToTreadmill(message);
}
```

Figure 7. Screenshot of code 3

In the code, there are two methods that we used in our Application: Start the Treadmill and Stop the Treadmill. We first wrote the code to start the treadmill. We string a message called "AA080008AB" which is the code that the engineer gave us that is used to start the treadmill. When we want to start the treadmill, we would call this method, and it would send this code, which is stored in the String named "message", to the treadmill. When the treadmill received the message, it would automatically start the treadmill. This message would be sent to the treadmill when the AI detected that the user needed to rest, or it would also stop the treadmill when the user chose to press the button on the screen. The second method, which is used to stop the treadmill, has the same logic as the first one. The only difference is that the second method made "AA090009AB" as the message, which is specifically used to stop the treadmill.

4. EXPERIMENT

4.1. Experiment 1

We would want to test out AI face detection's accuracy with people with different skin colors. This is a blind spot we want to test out because we want a variety of people using our Application, and it is important that AI can give out the right result for everyone in order to protect their safety.

We will design an experiment with different skin color people participate in. We will let them stand in front of the camera and make different face expressions to see if the Application can correctly indicate it. Then, we will let them run on the treadmill to see if the Application can still correctly examine their facial emotion. Experiment is set up to test if AI can determine the facial expression of different people, then, we can test if AI can correctly determine people's facial emotion when they're in motion. This is what the AI is supposed to do because they should determine if the person is tired when they're running. There isn't any control data because we're just testing if the same application can make the right decisions on different people.

Different Skin Color Testing			
	White	Asian	Blacked
Standing	Detected	Detected	Not detected
Exercising	Detected	Detected	Not detected

Figure 8. Figure of experiment 1

As shown in the data, our Application could not successfully detect the emotion of people in dark skin color. We can see that no matter when standing or in motion, both white and asian could be accurately detected when they're tired, but people like blacked or with dark skin color could not be detected. This result didn't met our application because we did expected that blacked people's face could not be detected during exercise because previous research has shown that the error of detecting blacked female's face by AI has the maximum of 34.7% when usually with white women it is 0%[6]. However, we didn't expect that AI couldn't detect the face emotion when standing in front of the camera either. We believe it turned out this way because AI uses the outline of people's face features to detect their face; however, blacked people due to their skin color, don't have a very obvious shadow and outline on their face for the AI to detect, so many time, AI couldn't successfully recognize blacked people's face and their emotion. Another big effect of why AI can't detect people's face when they're exercising is because when people are running, their face would be in a great motion going up and down, so they're face would be more vague than when they're standing in front of the camera, making AI hard to detect they're face clearly.

4.2. Experiment 2

We would also want to test out if AI face detection could successfully determine the face expression of elders. Our Application is created for all people to use, and there are also elders trying to exercise. This is a very important part of our Application because many times an elder needs more protection on the treadmill than youth. An Application should be able to accurately detect both young and old people's tiredness in order to provide effective protection.

We would set up the experiment with an elder and a youth involved. We will let the youth do the exercise with the Application beside and let the person make a tired expression after running for around 5 minutes. Then, we will record if the Application could regularly work with a young person. We set the experiment up like this to first make sure if the Application could accurately work. After that, we will let an elderly person stand in front of the camera and start exercising. The elder could slowly exercise until they're tired, and we can record if the Application could automatically stop the treadmill before the elder needs to stop the treadmill by hand. This is set up to see if the Application could detect tiredness from an elder's face, but the experiment needs to be set up with people beside to protect the elder if the Application does not work.

Different Ages Tiredness Detecting		
	Youth (Asian)	Elder (Asian)
Standing	Detected	Detected
Exercising	Detected	Detected

Figure 9. Figure of experiment 2

As the result of the experiment, we can see that AI has no problem detecting a user's facial emotion no matter the age of the user. This surprised us because we thought that as people get older, their tiredness would be harder to show because the muscles on their face would sag and cause them not be able to make a lot of obvious facial emotion. Surprisingly, AI does not seem to have any problem with detecting tiredness on it, which is a good thing because this Application has the purpose of protecting the elderly's safety when exercising. We believe that the experiment succeeded because when training the AI, the programmer already fed a lot of people's face emotion including different ages in it, so the AI has the ability to detect emotion in elders. Another reason is because we used an Asian elder's face, which avoids the possibility of not detecting the facial emotion of elders with other skin color. If we used the picture of another elder with different skin color, the result of the experiment may not be as same as what we have now.

5. RELATED WORK

In order to prevent injuries from over exercising, many scholars also bring up a solution of including more exercise intervention before starting the main exercise. Lauersen tried to involve stretching, multiple exposures, proprioception training, and strength training before the main exercise to test if these exercised could help reduce the rate of injuries in sport exercising. As a result of their test, all of the warm up above except stretching could contribute to the decrease of the rate of injuries, both acute and overuse [7]. These exercises work as a warm up for the main sport. They could help slowly build up the muscles for the person and contribute to their further exercise, it could also help the person to warm up first so they feel overstretched if they start exercising immediately. As experienced, warming up before exercising could significantly decrease the possibility of injuries during exercise [8]. This is a pretty effective solution for preventing injuries. For instance, proprioceptive training could effectively prevent ankle sprains[9]. However, this solution also has limitations. There could be the possibility of people getting injured after adding more exercise into their schedule, and there could be the possibility of injuring during heavy exercise like proprioception training. This would be a great solution with the involvement of our Application. When warming up, the user coil put our Application by side and let our Application prevent the user from overexercising or injuries during the warm up part.
Another method that people proposed is to create an exercise schedule. It could be to create a fixed rest day or week, or spend a week doing lighter exercise and a week doing stronger exercise. Breaking the days into high and low intensity could prevent continuous workout causing injuries [10]. This is an effective solution. Creating and following a schedule could prevent the person from continuous exercising for a long run and causing exercise. A limitation for this is that creating a schedule is a continuous thing that the person needs to follow. It could prevent the user from over exercising within a month or a year, but it could not prevent the user from injuries in a one-day exercise. There are always times that the person forgets about their schedule and exercises more than they could in a day, which would suddenly cause injuries. Our Application focuses more on the safety of everyday workout. The user only needs to open and put our Application on side when exercising, and our Application could help users during the short time exercise that a schedule could not cover.

People also use electronic tools to prevent themselves from over exercising. For instance, many people use smartwatches as a way to warm themselves when exercising. When wearing smart watch, people could track their heart rate and working load with it. When user's heart rate is too high or too low, or their working load is too much, a smart watch could give out effective warning to the user. In addition, people can check their heart rate every morning to see if they're prepared to do exercise for that day [11]. This solution is especially effective because users can use it to track their body whenever they want. Also, usually the smart watch could give out warning and sometimes even call the doctor when the user could not by themselves. However, the limitation for this tool is also obvious. Smart watch could only give a warning to the user when they're exercising, and sometimes when exercising, the user may be too focus that they would ignore the warning. If the user ignore the warning, then the smart watch couldn't do anything anymore. Our Application solved this problem by connecting our Application to the device. Therefore, when the user is tired and did not see our recommendation to stop the treadmill, our Application can force to user stop by stopping the treadmill before the user over exercised.

6. CONCLUSIONS

Some limitations of our project are that in order to activate it, the treadmill needs to have bluetooth connection, and it needs to be bluetooth low energy (BLE) connection. Nowadays, most treadmills are using BLE as their connection, so in most cases, our Application could work with the treadmill. However, many treadmills also use Bluetooth FTMS, a latest bluetooth specifically for fitness equipment, for connection purposes, which our Application would not work on [12]. In order to fix this limitation, we would want the Application to be available for both regular bluetooth and BLE connection. We could implement another bluetooth connection program into the Applicationand make both bluetooth and BLE program running when searching for devices. Then, we could connect to any device based on the bluetooth that the device uses. Another limitation we have is the Application is only available when connected to the internet because Vertex AI is an online program that would need internet support to use it. This would be a problem if the user wants to exercise in a place that has no internet. Many AI works based on the real-time data online, so they would only function when connected to the internet, Vertex AI is one of them. However, there are also offline AIs that work based on the database they already have [13][14]. We think that we could add another facial detection program that we can use without the internet. If we have more time with our Application, we could train our own AI and use it for our Application. If we train our own AI and download it, then the AI would not need the internet to use it because it has its own database, which could perfectly solve this limitation.

In the current society, more people started to value their health more. People start to exercise, and there are many ways to exercise. Some people start doing sport, and studies show that when doing exercise, the percentage of overuse injuries every year is 42% and 33% for individual and team sports [15]. Some people start trying fitness equipment. When trying a new fitness machine, such as a treadmill, there is always the danger of not being able to balance between the amount of exercise you want to do and the amount of exercise you can do. This balance is how people prevent themselves from over exercising and hurting themselves. When people lose their balance, there is the need for a tool to help them balance it out, and under this idea, our Application is created. The purpose of our Application, TreadGuard, is to help the user exercise safely, and we want to use it as a guard for people's exercise adventure.

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