2020

Chess Robot with Dynamic Difficulty Adjustment Based on Facial Expression Recognition

--- a robot, can play chess with people and adjust the difficulty of the game based on the emotion of opponent.

INTELLIGENT ROBOTIC SYSTEMS PROJECT

ZHANG ZEKUN (A0215485B)
CHENG YUFENG (A0215320Y)
SHI ZHAOHENG(A0215413U)

NUS National University of Singapore | ISS INSTITUTE OF SYSTEMS SCIENCE

NATIONAL UNIVERSITY OF SINGAPORE | INSTITUTE OF SYSTEM SCIENCE

Content

Project's Background

There are so many entertainment activities in human society, such as sports, computer games, movies, and so on, which seems that there is no new and potential entertainment field for us to explore. However, it still misses something interesting, such as robotic entertainment.

Robotic entertainment is an area that is worth exploring, so we want to find a game that we can teach robots how to play and let them play with human in order to know more about this field. Chess is a good choice for us because chess is a popular puzzle game all over the world with lots of players, which means that our robot can be tested by everyone who can play chess and we can improve it based on the feedback of players. So, we will combine the chess player AI and robot to build a chess player robot that has different modes for different levels of players.

However, there is a serious problem. As we know, chess players have different levels, high-level players want to have tough games with the robot, and beginners are willing to have the easy one. But they may not know which level they are, for example, some mid-level players think they are high level, and they choose the tough mode AI, which may cause them to lose the game very quickly and do not enjoy the game. So, we will design an algorithm that can automatically adjust the difficulty according to facial expression, for example, if the player has a painful face that means the game is too tough for him/her, the robot will make the game easier, if the player still feel it is hard, the robot will continue to reduce difficulty.

Related Work

- DDA based on Facial Expression Recognition: We referenced some papers discussing DDA (*Zohaib, Mohammad. "Dynamic difficulty adjustment (DDA) in computer games: A review." Advances in Human-Computer Interaction 2018 (2018).*) and facial expression recognition (*Minaee, Shervin, and Amirali Abdolrashidi. "Deep-emotion: Facial expression recognition using attentional convolutional network." arXiv preprint arXiv:1902.01019 (2019)*).

  Our facial expression recognition model was trained based on an open dataset (*Carrier, P. L., Courville, A., Goodfellow, I. J., Mirza, M., & Bengio, Y. FER-2013 face database. Universit de Montreal, 2013.*).

  Investigation of how two techniques can be used together (*Carrier, P. L., Courville, A., Goodfellow, I. J., Mirza, M., & Bengio, Y. FER-2013 face database. Universit de Montreal, 2013.*);

- Robot chess: robot chess has some sophisticated implement solution (*Srivatsan, R., S. Badrinath, and G. Lakshmi Sutha. "Autonomous chess-playing robotic arm using Raspberry PI." 2020 International Conference on System, Computation, Automation and Networking (ICSCAN). IEEE, 2020.; Golz, Jens, and Rolf Biesenbach. "Implementation of an autonomous chess playing industrial*

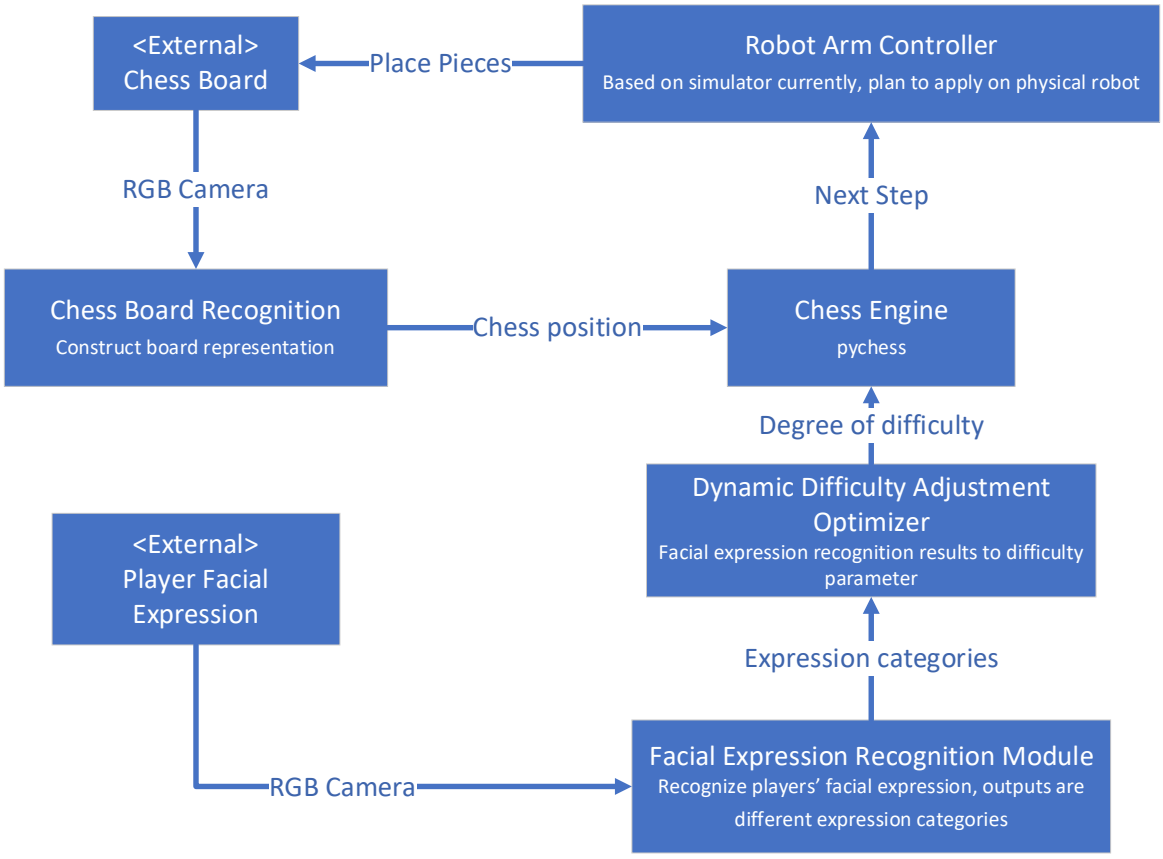
robot." 2015 16th International Conference on Research and Education in Mechatronics (REM). IEEE, 2015.), we referenced these solutions to build our system.

Innovation

Our work contains three parts: Chess Robot, Facial Expression Recognition, and Dynamic Difficult Adjustment. The Chess Robot is to control the robotic arm moving pieces to the target location. The Facial Expression Recognition is to get the feeling of player according to his/her facial emotion. The Dynamic Difficult Adjustment is widely used in video game industry, which is able to percept players' gaming experience and change games' difficulty accordingly. We will talk the three parts in detailed in the Technical Solution section.

Though some work has been done for each individual part, no work has been done in combing all these three parts together. Having seen the good performance of applying DDA on video games. We plan to adopt the similar strategy to apply facial expression based DDA on chess game. Using facial expression captured from camera to detect the players' emotional states and then adjust game difficulty level dynamically according to these emotional states.

System Architecture



This diagram describes the high-level architecture of our chess robot system.

Technical Solution

Chess Robot

Firstly, we will use a robotic arm to pick up and drop down pieces, which will use the inverse kinematics technique. In order to prevent hitting the chess pieces, the gripper of the robotic arm must grab the chess pieces from top to bottom.

Secondly, the camera on the robot will capture the photo of the chessboard from top to bottom and recognize every type of chess piece, which allows the robotic arm to catch a specific piece accurately.

Moreover, we will find a chess player AI that can adjust the difficulty of the game and integrate this AI into the robot control system. The chess player AI will tell the robot to move which chess pieces and move to specific position.

Finally, there will be another camera on the robot that is used to capture facial expression of the player and then the photos will be processed by a model that can recognize the emotion of the facial expression, such as happy face and angry. According to the output of model, the system will adjust the difficulty to improve the game experience.

In this stage, We use gazebo as the simulation software to achieve the above-mentioned requirements proposed by ourselves. Of course, We will apply these ideas to real robots if we have chance.

Facial Expression Recognition & Player Experience Inferring

- **Facial Expression Recognition:**

  Emotions are very important in the daily communication of human life. It can help better understand the human feeling. More specially, emotion recognition can be performed using different information, such as face, EEG, and even text. The most popular way to do emotion recognition is through facial expressions as they are visible, so people can easily recognize the emotion without too much prior knowledge. In our case, the facial emotion is also easier to get during the game when compared with other two ways.

  Recently with the big success of deep learning model and especially convolution neural networks on computer vision tasks, many of them are applied on image classification task. However, for facial expression recognition, many of clues come from only a few parts of the face, such as eyes and mouth. According to this scenario, the model should only focus on the important parts of the face.

In this project, we used an end-to-end convolution neural networks and used the attention mechanism to focus on the meaningful part of the face.

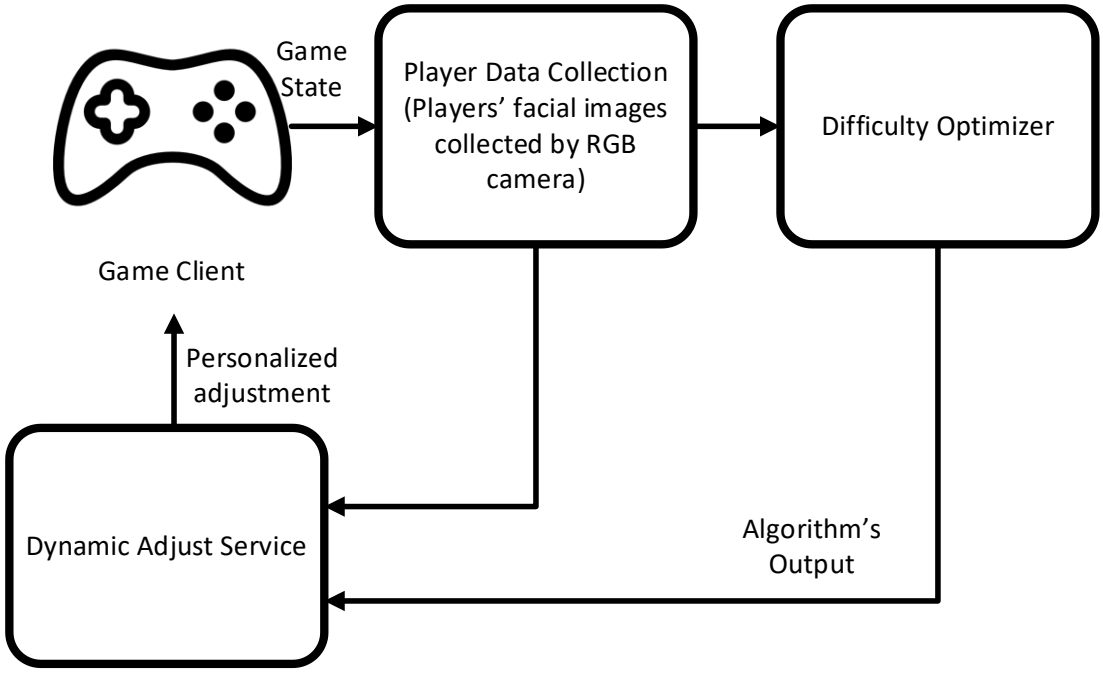
- **Player Experience Inferring:**

  Player experience plays a vital role in the whole game. Thus, it is important to know how to evaluate the player experience during the game process. Traditional methods are using qualitative methods and includes collecting subjective data from direct observations, interviews and think-aloud protocols. However, there are also some shortcomings in this method. Because some players will act differently when monitored. This shortcoming drive research towards quantitative methods which dependent on objective data. So far, there are some researchers showing that facial expression emotion can be used to evaluate the player experience.

Dynamic Difficult Adjustment

Dynamic difficulty adjustment (DDA) is a method of automatically modifying a game's features, behaviors, and scenarios in real-time, depending on the player's skill, so that the player, when the game is very simple, does not feel bored or frustrated, when it is very difficult. The intent of the DDA is to keep the player engrossed till the end and to provide him/her with a challenging experience.

In our project, we applied DDA on chess, whose gaming experience would become terrible when two opponents are mismatched. Some research has set up a general framework of DDA, we also built our Human-Robotic Interaction (RHI) based on it:



In our general DDA process, robot will use RGB camera to percept players' facial expression, then it will estimate suitable difficulty for certain player based on the perception. After that, some arguments indicate how to adjust the chess engine.

Business Value

As we know, owners of a leisure and entertainment venue, such as coffee shop, bar, and so on, always wants to keep customers in their places. To achieve this purpose, they will put some entertainment facilities that are free in their store, so customers may enjoy those things and stay longer, which will make them spend more money. For example, some coffee shops have some books for people to read, which can attract guests who like to read, and those people will spend more time and money in the shop. Moreover, the shop that has many customers will continue to attract more people, which is called the herd effect. There must be a scene you have seen like that one restaurant is already full, and many people are queuing, while the other restaurant next to it is almost empty. So, it is significant for an entertainment venue to make consumers spend more time in the restaurant.

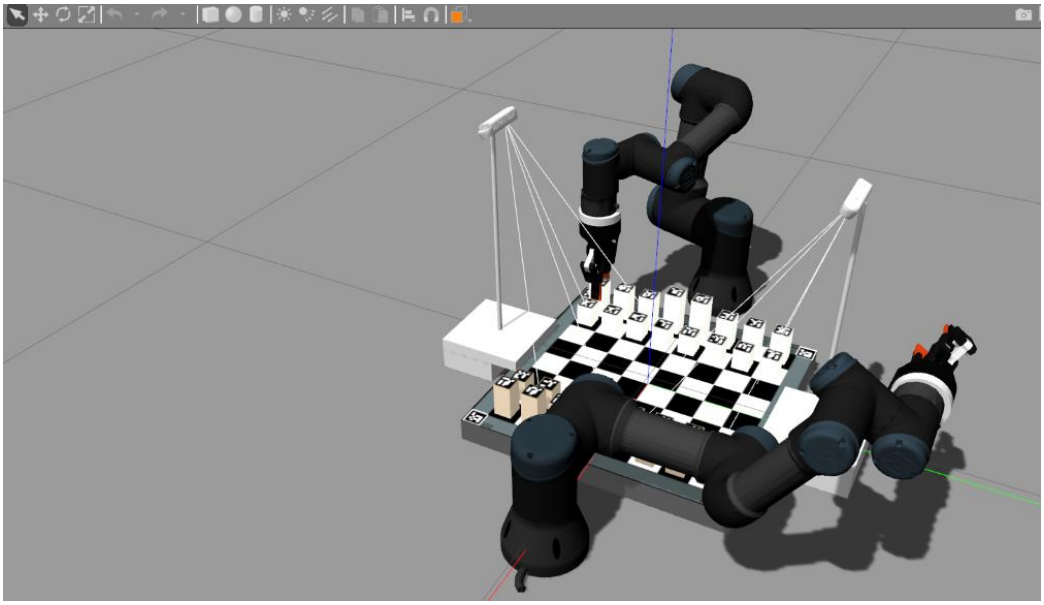
As we mentioned before, the key thing to make people come to the shop. To display a robot in the shop may be a fantastic trick. For example, a robot arm can cook simple food like fried eggs and pour milk for customers automatically and a robot that works as a restaurant waiter has the ability to deliver meals to guests. All of them are not cheap and can be easily replaced by human workers, but those robots indeed bring more people to their shops. Because it is interesting to see a robot work like human, people love that. And chess is a popular entertainment project, which has a large number of players. So, our robot will be a good choice to keep in the shop for customers to play with, which can attract people. Also, our robot can dynamically adjust the difficulty of the game according to the facial expression of the player, so players of all levels can enjoy playing with the robot, which can make customers spend more time in the shop.

On the other hand, our robot can also act on elderly people with Alzheimer’s. As we know, to make people with Alzheimer’s play some puzzle games that can force them to use their brains. Chess is definitely a popular puzzle game, which can train people's strategic thinking. So, playing with our chess robot may help the elderly to get rid of Alzheimer’s. What’s more, our robot can adjust the difficulty, so the game wouldn’t end so early, which can better train people with Alzheimer’s.

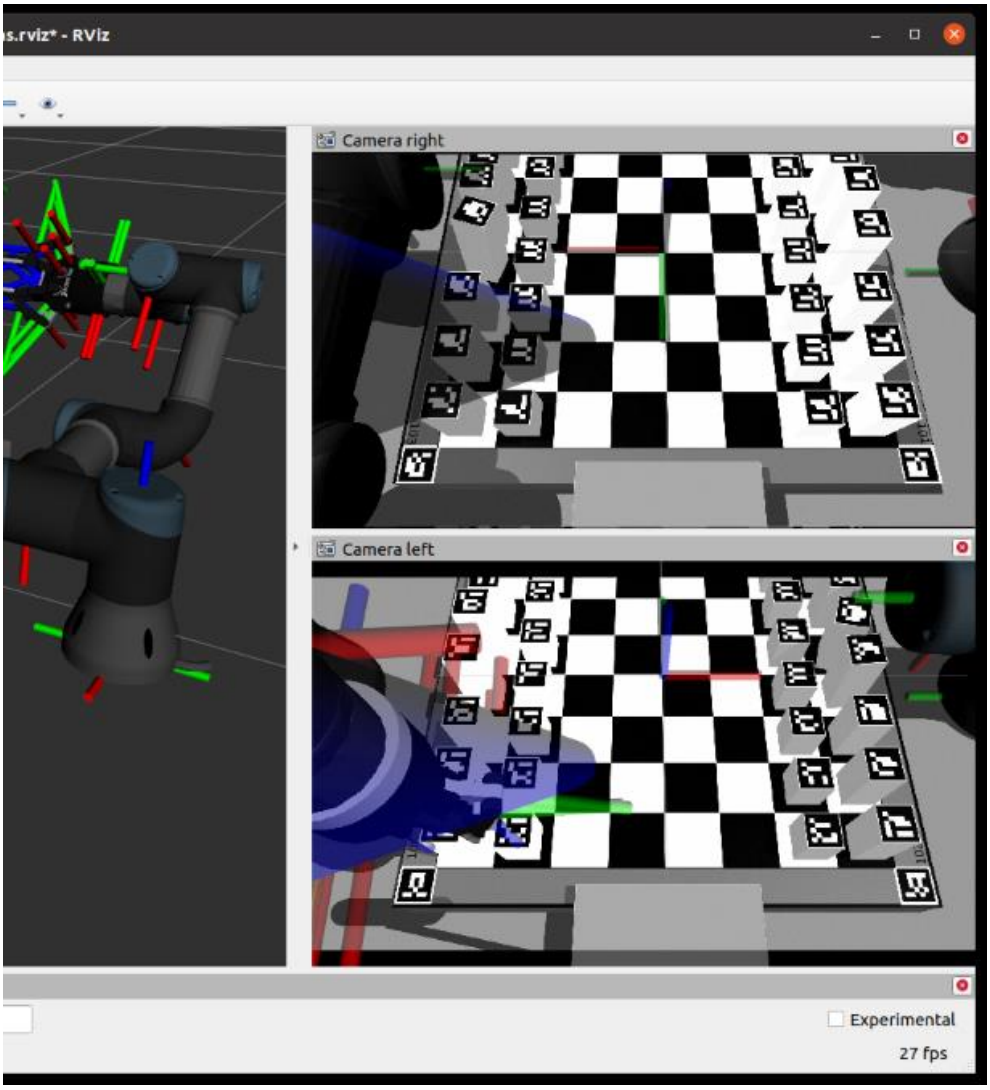
Project Progress

What we have done

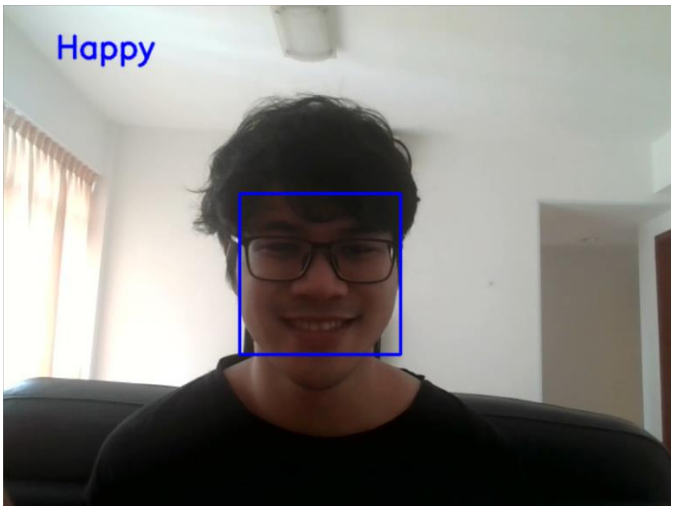
- We have implemented robot arm control in gazebo, which can grip and place piece.

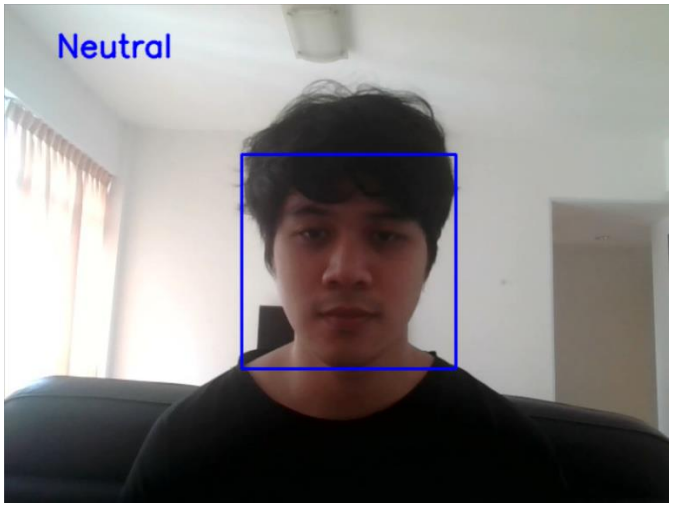


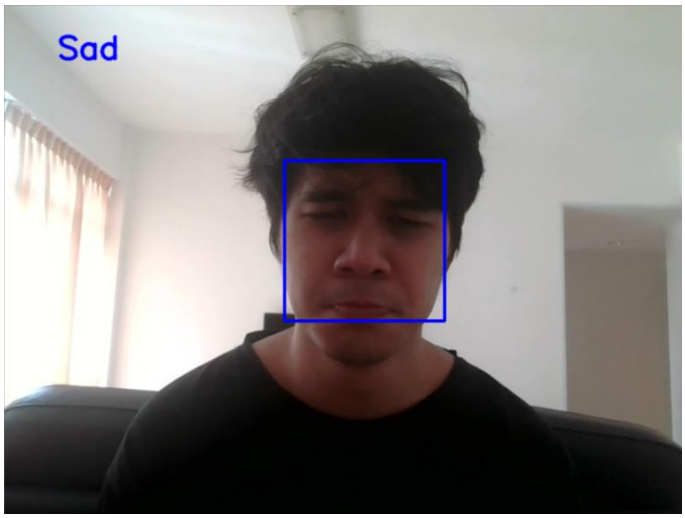
- We have placed virtual cameras into our simulator environment, which can capture images then recognize chess position.



- The facial expression recognition system is ready, we can get different expression categories form it.







What we plan to do

- Implement algorithm to utilize expression categories to infer user experience argument, which drive the dynamic difficult adjustment module.
- Try to use physical robot arm to replace the simulation part.