The building of the Eva Face

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1 Abstract

In this project, we aim to simulate human facial expressions using a robot's face. Drawing inspiration from Columbia University's open-source project, Eva, we are constructing the robot. Simultaneously, we're sampling facial features and abstracting them into individual points, controlled by servos, termed ANU (Actuated Neuromuscular Units), to mimic human facial muscles. Leveraging literature, we've translated the six basic human expressions into data point matrices for ANU. Through adaptive learning from human expressions, we enable the robot to imitate a wider range of facial expressions.

2 Introduction

Facial expressions are a significant aspect of non-verbal communication. In our daily lives, we rely on different facial expressions to convey our feelings and attitudes to others, as well as to interpret the emotions, desires, and intentions of others. Facial mimicry is also considered a crucial stepping stone in the early social development of infants. Therefore, creating robots capable of automatically mimicking various human facial expressions will facilitate more natural robot social behaviors and further encourage stronger human-robot interaction.

In this project, we aim to draw inspiration from Columbia University's open-source project, Eva, to build our own robot. Simultaneously, by incorporating facial expression processing methods from other research papers, we intend to enable the robot to make expressions similar to humans. As the robot lacks the innate ability to comprehend human facial expressions, we must convert human expressions into data that can be interpreted and executed through servo motor movements.We sample facial features and abstracting them into individual points, controlled by servos, termed ANU (Actuated Neuromuscular Units), to mimic human facial muscles. Leveraging literature, we've translated the six basic human expressions into data point matrices for ANU. Through adaptive learning from human expressions, we enable the robot to imitate a wider range of facial expressions.

3 State of the Art

Our project references the following six papers:

Smile Like you mean it: Driving Animatronic Robotic Face With Learned Models: This paper details the algorithm for robots to adaptively learn human facial expressions.

An Open-Ended Approach to Evaluating Android Faces: This paper provides a method for quantifying the effectiveness of robot facial imitation.

Design Concept of a Human-like Robot Head: This paper describes the considerations required to build a robot head.

Human-Like Artificial Skin Sensor for Physical Human-Robot Interaction: This paper mainly discusses the production of robot skin and its tactile feedback. We hope to use this paper to help us make the robot's facial skin.

Study on Face Robot for Active Human Interface: Mechanisms of Face Robot and Expression of 6 Basic Facial Expressions: This paper describes the classification of human facial expressions and how to manipulate servos to imitate human expressions.

Facially expressive humanoid robotic face: This paper describes how to build a robot head from scratch.

Among them, *Smile Like you mean it: Driving Animatronic Robotic Face With Learned Models and Study on Face Robot for Active Human Interface: Mechanisms of Face Robot and Expression of 6 Basic Facial Expressions* are the core papers that our project algorithm refers to. *Study on Face Robot for Active Human Interface: Mechanisms of Face Robot and Expression of 6 Basic Facial Expressions* focuses on the classification of human facial expressions. The paper points out that all human facial expressions can actually be divided into six basic expressions: Neutral, Surprise, Fear, Disgust, Anger, Happiness, and Sadness. Other expressions can be regarded as combinations of these six basic expressions. At the same time, the authors of the paper also extracted the data characteristics of these facial expressions and divided them into 68 basic points of motion. By cutting the face into these 68 basic points, we can convert the continuous image data transmitted during the expression simulation process into discrete matrix data related to these basic points. In this way, the robot can extract the basic point information of the expression in a picture to control the deflection angle of the relevant servo and achieve the effect of expression imitation.

Smile Like you mean it: Driving Animatronic Robotic Face With Learned Models provides an algorithm that allows robots to adaptively learn expressions. The paper uses the algorithm mentioned above and merges the 68 basic points of AU mentioned above into 24 basic points of AU. At the same time, the author also designed an algorithm that allows the backend to decode the matrix containing 24 basic point information into the corresponding facial features. Using adaptive learning, the robot can adjust and optimize its expression simulation algorithm model by constantly comparing the expressions it imitates with the original expressions. In the end, the author also gave the experimental results in the paper, which were not ideal. He believes that using only 24 basic point information to imitate may lose some of the feature information of facial expressions. In the project, we may use more basic points for improvement.

The paper Facially expressive humanoid robotic face provides some open-source code. This code is mainly related to servo control, allowing us to use the relevant interface of Raspberry Pi for servo control. This article is related to Smile Like you mean it: Driving Animatronic Robotic Face With Learned Models, and only includes the control of 24 basic servos. The author also provides encapsulation of servo control corresponding to the six basic expressions, making it easy for us to call directly.

Another open-source code controls eye movement. It also uses the relevant interface of Raspberry Pi to control the movement of the servo to control the movement of the eyes. Since more servos are used, we can make the robot make more flexible eye movements. It also provides optimization solutions for the above code.

Facially expressive humanoid robotic face provides a complete robot building process, including 3D printing parts and silicone face production. By replicating its content, we hope to first complete our own humanoid robot.

4 System Description

We have decided to continue testing the algorithm of Smile Like you mean it: Driving Animatronic Robotic Face With Learned Models, using 24 basic AU points. The challenges are:
1. If we use the original code, can the deflection produced by the servo controlled by the basic AU point meet the expected effect?
2. Where should we find the sample test points?

As for the construction of the robot, we hope to follow the construction guidelines provided by Facially expressive humanoid robotic face,and we have started to build it. We have encountered several problems:
1. Some 3D printed parts do not match and need to be manually modified;
2. The silicone face we prepared is inconsistent with the material provided, and we are worried that this will affect the servo control.
3. We hope to use another open-source project to replace the original eye part, but we don't know if

the sizes of the two are matched.

5 System Evaluation

Our project focuses on simulating facial expressions in robots, and therefore, we need two evaluation criteria:

1.Similarity between the robot's expression and the original image's expression. 2.Whether the imitation produced by the robot elicits the uncanny valley effect.

For the first point, the open-source project "EVA" has provided a good approach. It involves locating facial expression landmarks, identifying specific feature points and driver points for each facial expression. Then, by calculating the L2 distance between the feature points of the robot's simulated expression and those of the original image, we quantify the similarity between the two expressions.

However, beyond the mathematical algorithmic approach, assessing the resemblance of the robot's expression requires considering the subjective impressions of observers. This leads to the second criterion: whether the robot's imitation might trigger the uncanny valley effect. We referenced the paper titled "An Open-Ended Approach to Evaluating Android Faces," where a detailed questionnaire was used to assess the quality of the robot's imitation based on six basic emotions. We also aim to adopt a similar method to enhance the quality of our robot's imitation.

6 Our Work

6.1 The part we have finished

Based on Eva project, we reproduce it with our device and material. Through 3D printing and Laser cutting, we fabricate the structure of the head and the mould of the face. After concentrating the silica gel, we assemble the whole product.

During the replication process, we initially chose to manipulate the 9 action units (AU) points provided by EVA, but the results were not satisfactory. Attaching the wires directly to the silicone face only caused individual points on the face to indent. Therefore, we opted to use gauze to simulate the muscular tissue of the human face, allowing the force on the AU points to be distributed in the desired stretching locations.You can see the connect in Fig 1

We used cotton threads to connect the action units (AU) to servo motors. However, when we used the servo motors to manipulate these points, we found that the effects were only satisfactory in the eye socket area. The performance in other areas was significantly poor, and it was challenging to observe any noticeable changes.2

Figure 1: Connection

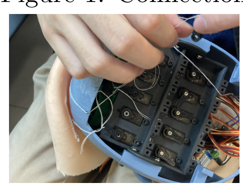

Figure 2: The connection of the servo

6.2 The part we want to improve

Figure 3: Communication with the author of Eva

We were honored to have a face-to-face exchange with the author of Eva's open-source project.You can see it in Fig3. During the discussion, the author provided us with many insights to address the challenges we were facing.

For instance, the use of Y-slots and conduits was suggested to handle distant points, making the effects more pronounced. After the exchange with the author, we realized that we had underestimated the complexity of reproducing the entire project.

The most challenging aspect of the project lies in training the parameters to enable the robot to produce facial expressions similar to humans. However, we couldn't reuse the parameters trained by the author for two reasons: there were significant differences in the silicone material we used compared to what the author used, and our method of manipulation differed from the one provided by the author. This necessitated retraining the entire model.

During the training, we encountered difficulties as the model's training was highly sensitive to the instability in the cotton thread and servo motor setup. Any loosening or detachment of the cotton thread or damage to the motor would cause severe changes in the robot's parameters during training. This resulted in the model being unable to perfectly replicate the facial expression, and the loss value would never converge.

6.3 The future work

Based on the aforementioned challenges, training the entire system proved to be excessively costly and lacked the ability for repeat training. Therefore, in the future, we are planning to adopt a partitioned approach to reduce the cost of training. Our plan involves dividing the entire face into five blocks, essentially breaking down the control of the 9 servo motors into 1-2 motors to control each specific block. This way, during training, we can individually train each section, and if there are issues in one segment, it won't affect the training of the others.

The author of Eva also proposed a new idea to reduce training costs, suggesting the use of mixed driving to control the entire device. While linear actuation performs well in muscle simulation, its non-replicability means that errors in one part would require retraining all parameters for that position. However, using drivetrains such as pneumatic systems that allow component replacement enables the new model to inherit the original parameters, significantly reducing training costs. We plan to implement pneumatic control in some areas to replace linear actuation.

7 Conclusion

In summary, our project aims to create a robot capable of mimicking human facial expressions. We've made progress in constructing the robot, incorporating adaptive learning from key papers, and referencing open-source code for servo control and eye movement.

References

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