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Secure and Usable Authentication Using Avatar Expression Blendshapes in Virtual Reality

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Project Page

Introduction

- VR controller-based authentication
→ Low or medium usability and vulnerability to observation attacks
- Facial-expression-based authentication
→ High usability and high resistance to observation attacks

We analyze and compare recognition performance and usability across six facial expressions.

RQ1: How do different facial expressions affect recognition performance in facial-expression-based authentication?
RQ2: How do different facial expressions affect usability in facial-expression-based authentication?

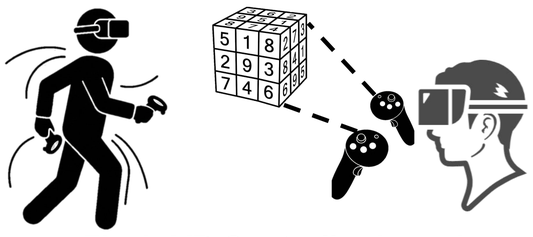

Fig 1: VR Controller-based authentication

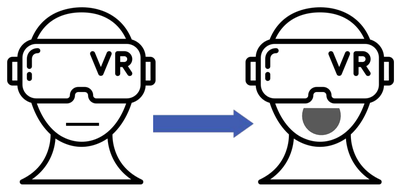

Fig 2: Facial-expresssion-based authentication

Authentication Framework

Facial Expressions for Authentication:
Using the **six basic emotions** defined by Ekman for authentication

Anger, Sadness, Disgust, Happiness, Surprise, Fear

System:
Input data: 63 types of blendshape from the face tracking system of the Meta Quest Pro
Model: 1D-CNN + ArcFace

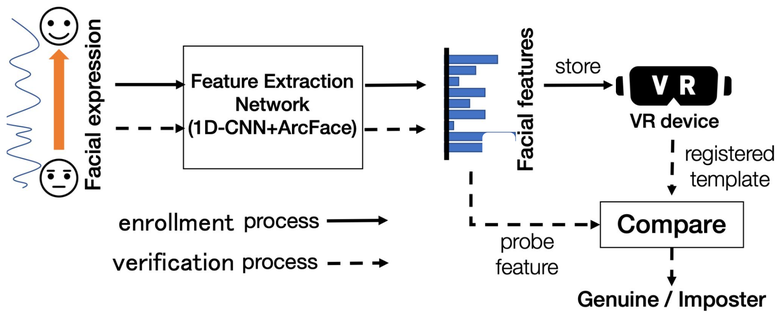

Fig 3: Architecture of Authentication System

Evaluation

Evaluation Method

Dataset: 2400 blendshape samples
20 participants ×
6 facial expressions ×
20 samples

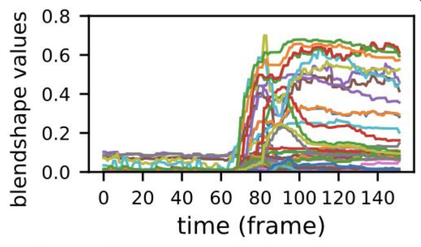

Fig 4: Example of blendshapes

- **RQ1: Recognition Performance**
Perform 5-fold cross-validation
Calculate **AUC** and **EER** for the home and public scenarios
  - Home scenario: All 20 participants as known users
  - Public scenario: 16 participants as known users and 4 participants as unknown users
- **RQ2: Usability**
Quantitative analysis using the **SUS** and **NASA-TLX**

Recognition Performance (Table 1)

- Best performance with **happiness** in both scenarios.
- Lower Performance with other expressions in the public scenario.

SUS Score (Table 2)

Happiness, Surprise ≥ 68 (Good Usability)

- Only non-negative expressions, centered on happiness, satisfied the practical SUS threshold.
- Negative expressions reduced usability.

NASA-TLX Score (Fig 5)

- **Happiness** has the lowest workload
- Negative expressions tend to result in higher workload.
- More natural expressions → lower mental and physical demand

Table1: Recognition Result for Each Scenario and Each Facial Expression

	home		public	
Expression	EER ↓	AUC ↑	EER ↓	AUC ↑
Angry	0.0383	0.993	0.0667	0.950
Disgust	0.0100	0.999	0.0417	0.978
Fear	0.0231	0.991	0.0917	0.967
Happiness	**0.00167**	**0.999**	**0.0167**	**0.999**
Sadness	0.117	0.954	0.105	0.952
Surprise	0.0410	0.989	0.175	0.891

Table2: SUS Score for Each Facial Expression

Expression	SUS Score
Angry	64.38
Disgust	61.62
Fear	66.50
Happiness	**71.75**
Sadness	67.88
Surprise	71.12

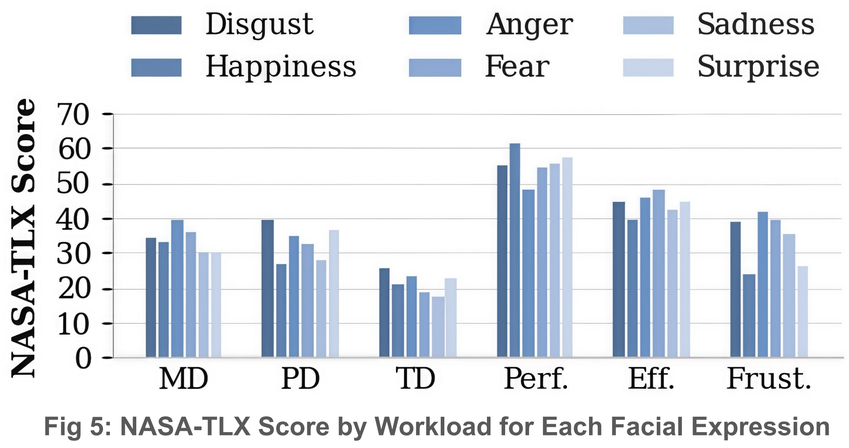

Fig 5: NASA-TLX Score by Workload for Each Facial Expression

Conclusion

RQ1
Happiness achieves higher recognition performance than other expressions in both scenarios, whereas recognition performance decreases for other expressions.

RQ2
In terms of both ease of use and cognitive load, happiness offers the highest usability.
Negative expressions tend to reduce usability.

Use Cases for Facial-Expression-Based Authentication

- For routine authentication, happiness serves as the primary factor, with other expressions (e.g. surprise or sadness) used as supplementary factors.
- For high-security authentication, combining happiness with another expression as a secondary factor improves performance.

Future Works

- Analyze the individual contribution of each blendshape to recognition performance
- Investigate performance and use cases by categorizing blendshapes (e.g. area around the eyes)
- Evaluate of continuous authentication