International summer school
"Biometrics – intelligent solutions"

July 2023

AI and Behavioral Biometrics

Nobuyuki Nishiuchi
Faculty of System Design
Tokyo Metropolitan University

1

Biometrics (Authentication)

Behavioral biometrics

Online lectures

Soft biometrics (Classification)

Usability, UX, VR

Lectures in Poland

Types of Biometrics

Physiological biometrics

Behavioral biometrics

3

Physiological biometrics

Fingerprint Vein Iris

Advantage: High accuracy

4

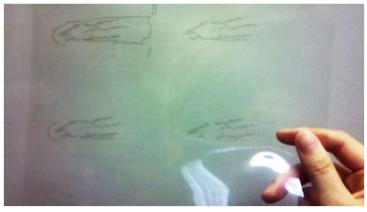
Disadvantage (Finger print)

How to make imitation fingerprint

plastic clay

Disadvantage (Vein)

How to make imitation finger (vein)



Print out vein pattern to sheet

Fill finger sock with artificial snow

Imitation fingers

6

Behavioral biometrics

Motion of hand Gait Keystroke

Advantage: Difficult to spoof

7

Disadvantage (Behavioral biometrics)

Low repeatability

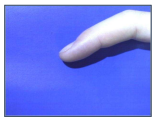
Subject A: 1st trail **Subject A: 2nd trail**

Different motion even if same person

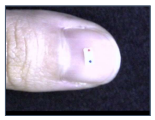
8

Three Approaches

(1) Combination of
biological data and dynamic data



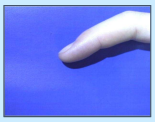
(2) Combination of
biological data and artifacts



(3) Combination of
biological data and others' biological data

9

(1) Combination of biological data and dynamic data



Basic idea:

Only dynamic data (no behavioral characteristics) is extracted from the motion of a particular body part. Based on this dynamic data, biological data of physical characteristics can then be compared.

→ Anti-spoofing

10

Advantages and Disadvantages

	Physiological biometrics	Behavioral biometrics
Advantage	High accuracy	Difficult to spoof
Disadvantage	Easy to spoof	Low Repeatability

11

Proposed Method

Focused on combing dynamic data with biological data (physiological biometrics)

- **Preventing "Spoofing"**
  Using the merits of behavioral biometrics
  (Difficult to make a moving imitation)

- **Expected high accuracy**
  Using the merits of physiological biometrics

12

Applications

1) Finger geometry
2) Finger veins
3) Irises
4) Eyelids

13

Applications to Several Types of Biometric Authentication

	Biological data	Dynamic data
Finger geometry	Contour of the finger	Finger motion
Finger veins	Vein pattern	Finger motion
Irises	Iris pattern	Eye movement
Eyelids	Contour of the eyelid	Blinking

14

Summary

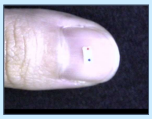
Pphysiological biometric verification (Biological data) combining dynamic data

- Strengths:
  Use of body motion in verification combines both biological data and dynamic data, thereby providing strength against spoofing

- Limitations:
  It was not always possible to completely match dynamic data between the reference and probe data due to missing images.

15

(2) Combination of biological data and the artifact



Basic idea:

User first attaches an artifact (a sticker) to fingernail of thumb or forefinger during enrollment step, and then, subsequently presents finger (biological data) with attached artifact to system. Position and direction of the artifact are uniquely detected based on an individual's biological data.

→ Cancelable biometrics

16

Characteristics of Biometrics

The ideal biological data for biometrics has the following five characteristics.

(i) Distinctive:
the biological data differs from one person to another.
(ii) Repeatable:
the biological data remains constant over a long period.
(iii) Accessible:
it is easy to view the biological data.
(iv) Acceptable:
it is not objectionable to show the biological data.
(v) Universal:
all people possess the biological data.

17

Problems of Biometric Authentication

Problem 1: biological data cannot be replaced.
For instance, if a user's fingers are lost, or if fingerprint information is stolen, the user cannot use a fingerprint identification system.
→(ii) Repeatable and (v) Universal.

Problem 2: all users are specified from the biological data.
As biological data is information linked directly with individuals, if biological data is leaked, the user can be specified using only the leaked biological data.
→(i) Distinctive.

Problem 3: biological data can be collected without consent of user.
In general, because biological features are exposed on the surface of the body, such as the face, fingerprints, and iris, it is difficult to keep these features located concealed from others.
→(iii) Accessible and (iv) Acceptable.

18

Study Objective

We propose a novel method of cancelable biometric identification that combines biological data with the use of artifacts and is resistant to spoofing.

Proposed Application of the System

Finger print
Finger shape

+ artifact

19

Features of Proposed Method

1) Cancelable biometric authentication:
   Registered information can be canceled by simply removing the artifact.

2) Controllable security level:
   The security level of the system can be adjusted by controlling the amount of permissible biological and artifactual data.

3) Non-necessity for the registration of unique biological information:
   Although the outline of the finger constitutes biological data, the information it provides in itself is not sufficient for individual identification.

4) Strength against spoofing:
   If the biological data and artifact are stolen, spoofing can be prevented due to difficulty of reproducing the biological data in relation to the artifact.

20

(3) Combination of biological data and others' biological data

Basic idea:

Using two or more individual's biological data combined with contact enables a system to capture each individual's unique biological data. It also captures the unique shape of the contact.

→ Another application of biometrics

21

Stereotype

- Biometrics = Authentication
- Biometrics for one user

New proposal

- Biometrics → another application
- Biometrics for multiple users

22

Proposed Application of the System

Proof

Memory

Security

Cooperation

Shared projects

Proof Agreement at the Same Time and Place for Two Users

Springboard of the Study

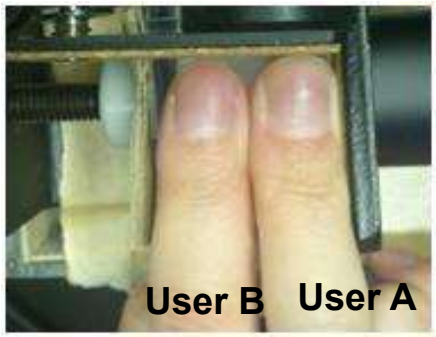
絆

KIZUNA

Bond

24

Selected Modality:
Laterally Contacting Fingers



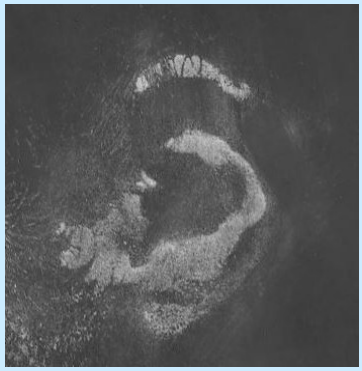
KIZUNA Identification

Combination of biological data
and others' biological data ⇒ **Create new something!**

25

Combination of
biological data and dynamic data

Earprint + Pressure



26

Pinna／Earprint

Pinna

- A pinna is a fan-like structure positioned at both sides of head and is visible from the outside of the human ear
- Proportions of uneven shape of ear does not change remarkably by aging

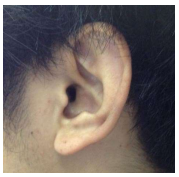


Fig.1 Pinna image

Features enable us to authenticate individuals

Earprint

- the trace, like a fingerprint, that remains when the pinna is pressed against the surface

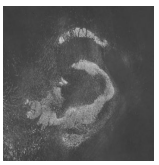


Fig. 2 Earprint image

27

Social Background

Netherlands
From around 1960, investigations using earprints left on windows and walls have been done. Earprints are found in about 15% of crime scenes [1].

England
In 1998, it was reported that a criminal was arrested using earprint [2].

France
Earprints of criminal arrested in 2013 were collected from 80 empty nest sites [3].

Comparative expertise on similarities in forensic earprint cases is conducted **manually by high-skilled police investigators**.

[1] L. Meijerman, et al., "Earprints in forensic investigations," Forensic Science, Medicine, and, Pathology, vol. 1, no. 4, pp. 247-256, 2005.
[2] BBC, "Police play it by ear," BBC News, 1999 (2017/7/1 accessed).
[3] The telegraph, "Thief caught after leaving ear print at 80 robberies", 2013 (2017/7/1 accessed).

28

Previous Research on Pinna/Earprint Authentication

① ＜Pinna × Pinna＞: A lot of research on Authentication

② ＜Pinna × Earprint＞: Few research on Authentication

③ ＜Earprint × Earprint＞: Few research on Authentication

29

Summary of Background

◆ Comparative expertise on similarities in forensic earprint cases is conducted manually by high skilled police investigator.

- Time consuming for verification
- Uncertainty of similarity determination caused by the human factor

◆ Research on the algorithms of matching between the two earprint images has not been studied

◆ “The outline of criminal investigation using earprints” [2] shows that the difficulty of matching is caused by the change of the earprint shape by the pressing force of the pinna.

30

Objective of Study

We develop an **earprints acquisition device** which allows for acquisition of the earprints changes (motion picture) caused by **pressing force** variations.

We also try the similarity measurement between **latent earprint image** and **continuous earprint images** obtained by the developed acquisition device.

As the first stage of this research, the template matching which is the most fundamental technique for the similarity measurement is tried.

31

Application of Proposed System for Crime Investigation

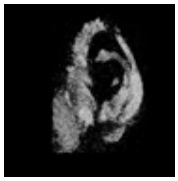
Crime Scene

Police Station

Earprints Acquisition System

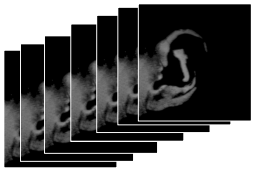
Suspect

Data base



latent earprint image

Verification



continuous earprint images

32

Expected Social Effect

Using the earprint acquisition device, in addition to collecting biometric information (fingerprints, facial photographs, etc.) of suspects, earprint information of suspects will be also acquired. Then, an earprint database will be constructed.

- Efficient criminal investigation using earprints
- Crime deterrence (crime prevention)
- Reduction of recidivism rate

（Recidivism rate in Japan：48.7%）

Ref. : http://www.moj.go.jp/content/001242255.pdf

33

Homework

Let try to come up with a new idea of biometrics based on one of the three approaches below;

(1) Combination of biological data and dynamic data
(2) Combination of biological data and artifacts
(3) Combination of biological data and others' biological data

Please summarize your idea to one slide of power point.
You don't need to check previous researches.

34

Title：XXXXXXX

Combination of data

XXXXXXXXX + YYYYYYYYY

Explanation of Basic idea

Text & Illustrations

35

AI and Behavioral Biometrics

Human Measurement

Biometrics (Authentication)

Behavioral biometrics

Online lectures

Soft biometrics (Classification)

Usability, UX, VR

Lectures in Poland

Soft Biometrics

Any anatomical or behavioral characteristic that provides some information about the identity of a person, but does not provide sufficient evidence to precisely determine the identity can be referred to as a soft biometric trait. Personal attributes like **gender, ethnicity, age, height, weight, eye color, scars, marks, tatoos, and voice accent are examples of soft biometric traits.** Soft biometric information complements the identity information provided by traditional (primary) biometric identifiers such as fingerprint, face, iris, and voice. Hence, utilizing soft biometric traits can improve the recognition accuracy of primary biometric systems.

Andrew McStay: "**Emotion** is an example of soft biometric trait profiling."

[1] Karthik Nandakumar & Anil K. Jain, Soft Biometrics, Encyclopedia of Biometrics pp 1235–1239, 2009.

[2] Andrew McStay, Emotional AI, soft biometrics and the surveillance of emotional life: An unusual consensus on privacy, Big Data & Society (BD&S), 2020.

Human Measurement

Soft biometrics (Classification)

Usability
UX
VR

Emotion

Satisfaction

Usability and User Experience

Definition of Usability

ISO9241-210:2010:

"The extent to which a product can be used by specified users to achieve specified goals with **effectiveness**, **efficiency**, and **satisfaction** in a specified context of use."

3 elements for evaluation

Effectiveness

Efficiency

Satisfaction

Effectiveness

Accuracy and completeness with which users achieve specified goals

Example:

It is possible to get a book

at an online book store.

Efficiency

Resources expended in relation to the accuracy and completeness with which users achieve goals

Example:

It is possible to get a book

at an online book store

in shorter time.

Satisfaction

Freedom from discomfort, and positive attitudes towards the use of the product

Example：

It is possible to get a book

at an online book store

feeling content.

Context of Use

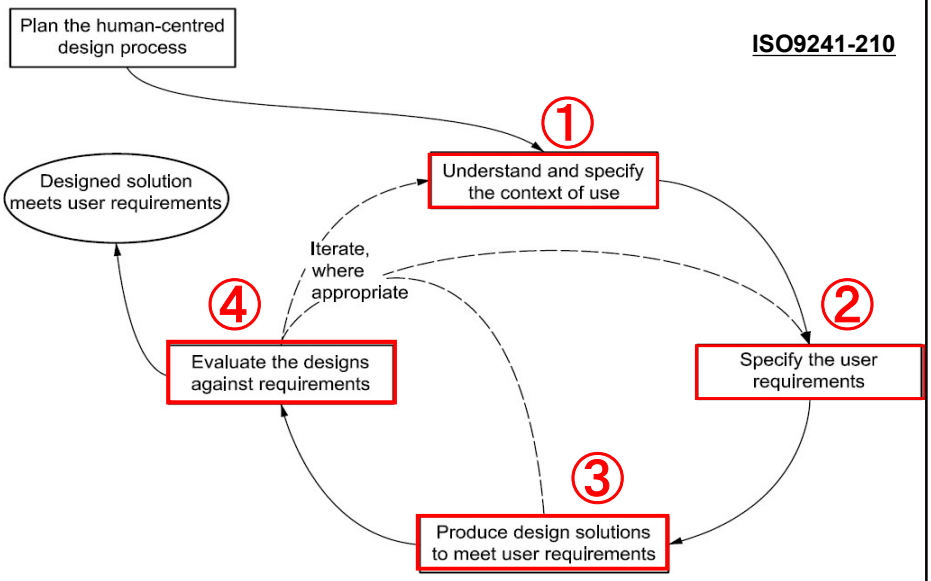
Users, tasks, equipment (hardware, software and materials), and the physical and social environments in which a product is used

Human-Centered Design

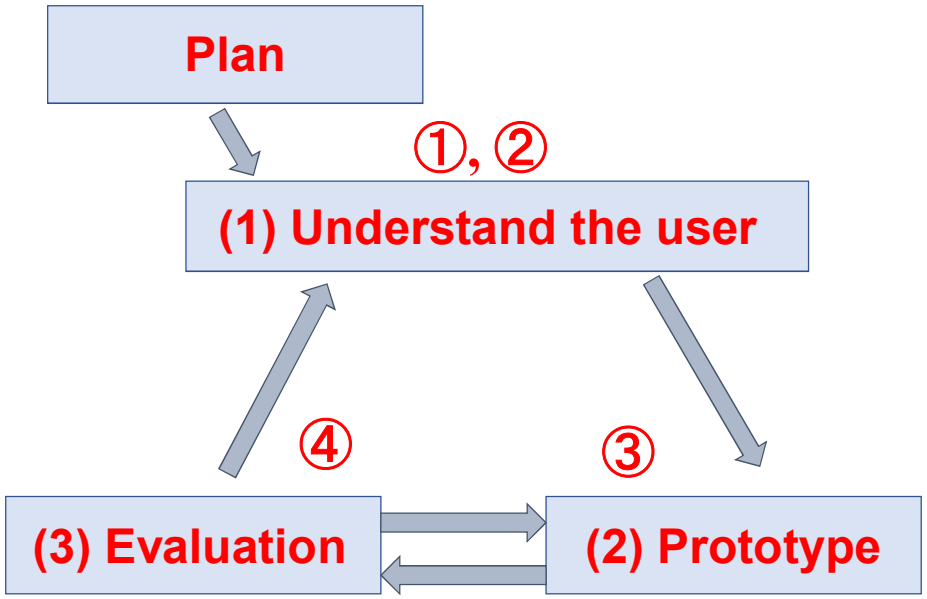
Approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques

ISO 9241-210

Human-Centered Design



Basic structure of HCD



Specific Method for HCD

(1) Understand the user
- Photo Essay and Photo Diary
- Persona
- Interview research
- Questionnaire research
- Scenarios and Personas

(2) Prototype
- Paper prototype
- Rapid prototype

(3) Evaluation
- Expert inspection
- Usability test

User Experience（UX）

Donald Norman

・Professor, Director of The Design Lab at University of California, San Diego

・Co-founder of the Nielsen Norman Group

49

UX: User Experience

ISO9241-210: 2010

Person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service

Significant meaningful experience

"Satisfaction"

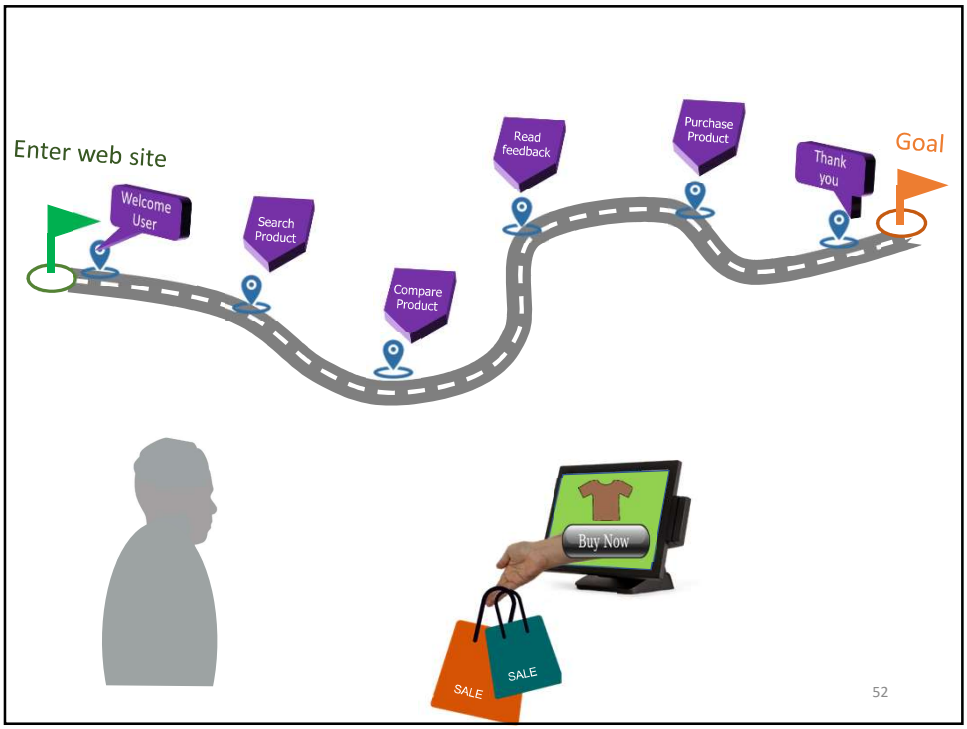
Usability

ISO 9241-210: 2010

> Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

Usability → **Effectiveness**, **Efficiency**, **Satisfaction**

51

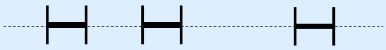


52

Usability and UX

Usability

Measuring time：Short period

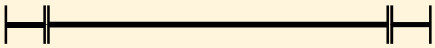


Operation Operation Operation

Measurement object：
Ease of use

UX

Measuring time：Long period

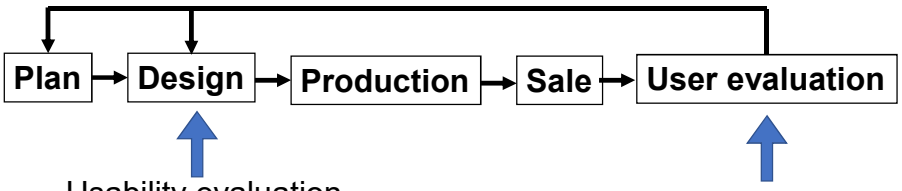


Before use During use After use

Measurement object：
Meaningful Experience

53

In Business Process



Usability evaluation

Usability laboratory

UX evaluation

Actual user's daily life

UX metrics (UX evaluation)

How can we measure/evaluate UX?

- Subjective evaluation
- User test

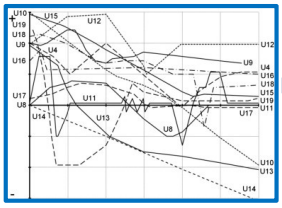
→ Expensive and time consuming

↓

How can we gather digital data of UX?
How can we obtain the data of long-period use ?
⇒ UX metrics

55

Statement of the Problem



UX Curve

Expert Teams

- ❑ Difficulty in classifying these data
- ❑ A Lot of line graphs/ High complexity
- ❑ Laborious task
- ❑ Requires processing times
- ❑ Requires interpretation from experts
- ❑ Difficulty in predicting the final satisfaction

Problems on Current UX Evaluation

Current evaluation method

- Interview
- Questionnaire
- Observation of User operations (User test)

Characteristics of UX evaluation

- Subjective evaluation
- Long evaluation period (UX)
- Different experience of each user

Problems → **Time consuming**, **Requirement of great effort**

Goal of the Study

How to get long period data from user's daily life?
How to evaluate UX data?

⇒ Get **Biological data** for UX evaluation
⇒ Use AI for UX evaluation

58

Our research group's studies

(1) Fingertip movement
(2) Eye movement
(3) Brain waves
→ Usability, Objective data (Biological data)

(4) UXPLOT
(5) UX and AI
→ UX, Subjective data

(6) Facial expression
(7) VR
→ UX, Objective data

59

Usability

(1) Fingertip movement

60

A new method for usability evaluation based on fingertip movements by image processing

- Based on the fingertip movements of a user during operation a system, some evaluation parameters are calculated. By using these data, the usability of the system can be evaluated.

Character of the method

- Applicable for various types of interfaces
- Semiautomatic evaluation by image processing

61

Usability

(2) Eye movement

62

Proposal of Usability/UX evaluation using eye movement analysis

Assuming user's state(searching or reading) from eye movement

This method is connected to Brain wave analysis

63

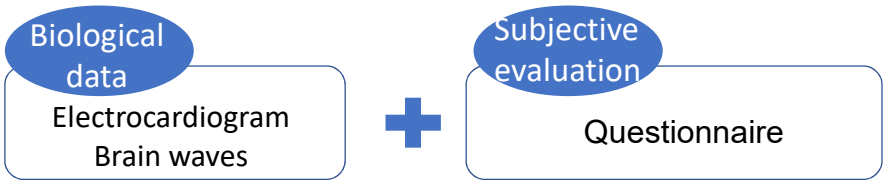
Usability

(3) Brain Waves

64

Proposal of Usability/UX evaluation using Eye Fixation Related Potential (EFRP)

Assuming user's state (searching, thinking or reading) and measuring workload from brain waves



The EFRP is based on eye movement.

Validation comparing subjective data and biological data

65

User Experience (UX)

(4) UXPLOT

66

Development of UX data Acquisition system
Proposal of UX evaluation method using this system

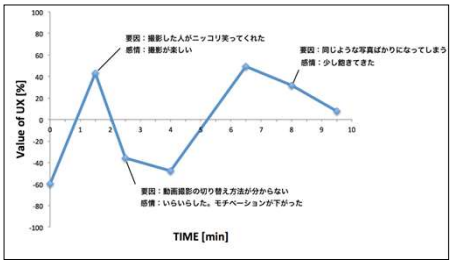
This system is used for long period evaluation and proposed as more useful evaluation system comparing current methods.

67

UX PLOT

Input UX value

Input emotion and reason



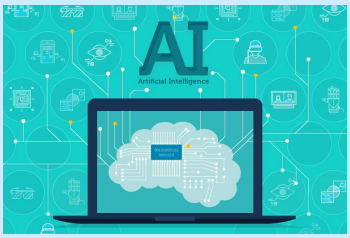
Example of visualization

Real-time acquisition of UX value using iPhone
→Comparing with UX curve

68

User Experience (UX)

(5) UX and AI

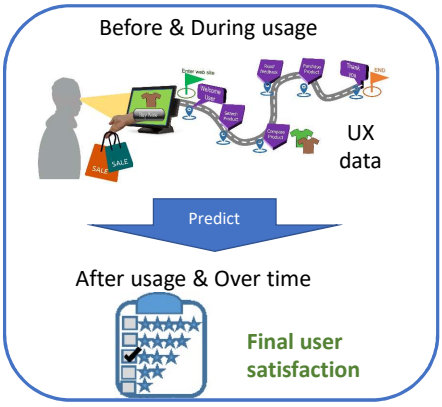


Introduction

UX (User Experience) has become increasingly important to keep users' satisfaction of products or services.

UX is a person's emotions and attitudes during usage of a products, systems or services. Additionally, it includes a person's perceptions of system aspects such as utility, ease of use and efficiency.

Objectives



Main Objective

- ❑ To propose a framework to predict final user satisfaction by user experience (UX) data using machine learning.

Specific Objectives

- ❑ To predict the final user satisfaction from UX data during products or services usage
- ❑ To predict the final user satisfaction using random ordering of user tasks in UX testing

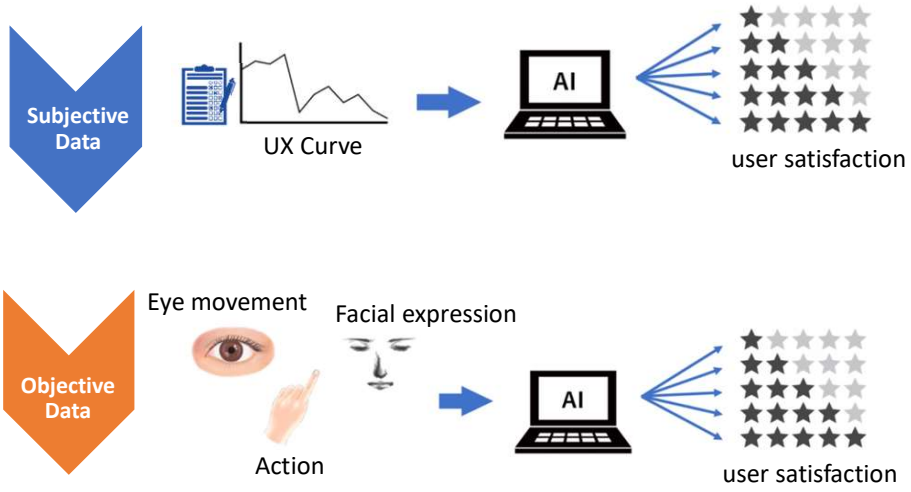
71

User Experience (UX)

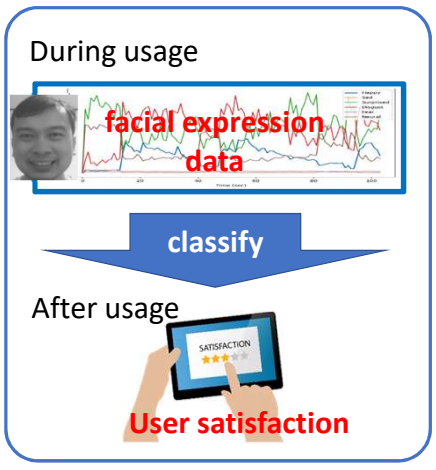
(6) Facial expression and UX

Classification of satisfaction using facial expression and AI

UX Evaluation in Practical Use



Objective of Study



Proposal of a framework to predict the user satisfaction of products or services by the facial expression data and machine learning.

74

User Experience (UX)

(7) VR (Meta verse)

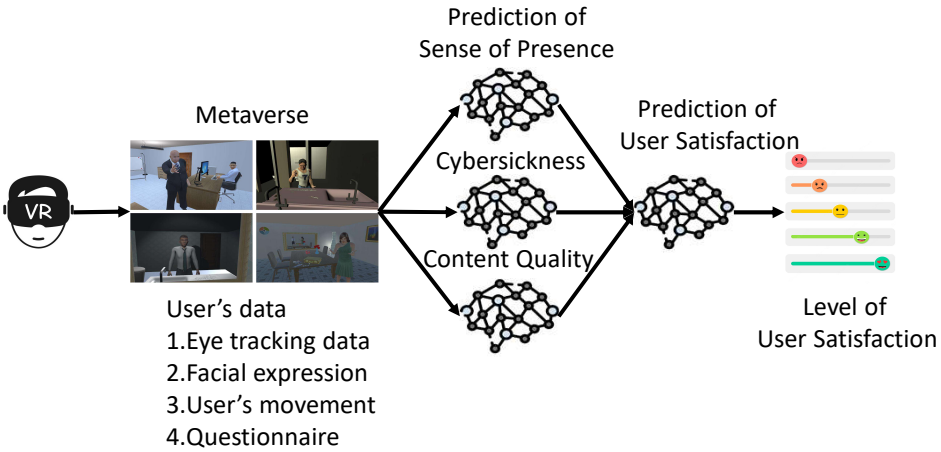
Classification of satisfaction (UX) of VR using biological data and AI

Proposal of a Framework for Evaluating User Satisfaction in Immersive Virtual Environments

- Our long-term study aims to develop a framework that can automatically classify level of user satisfaction while navigating in IVEs.
- The framework will use biological data from users to gain insight into users' emotions and attitudes and then use machine learning algorithms to identify patterns and make classification about level of user satisfaction.

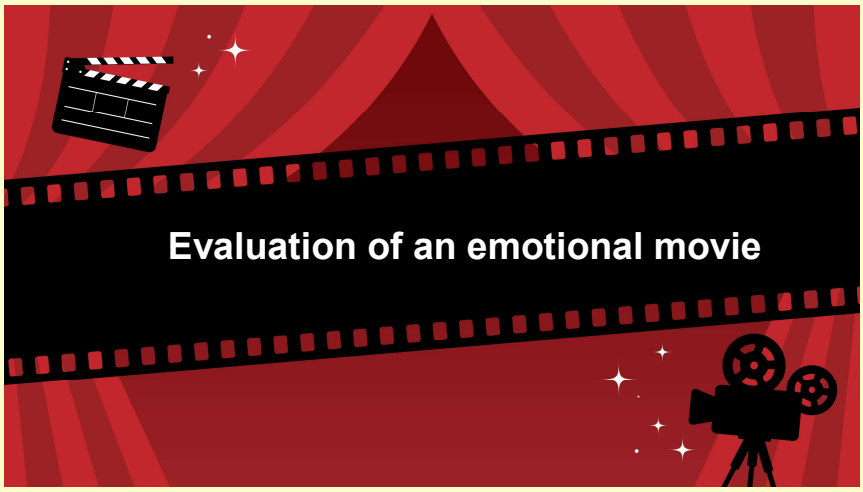
76

Envisioned Framework

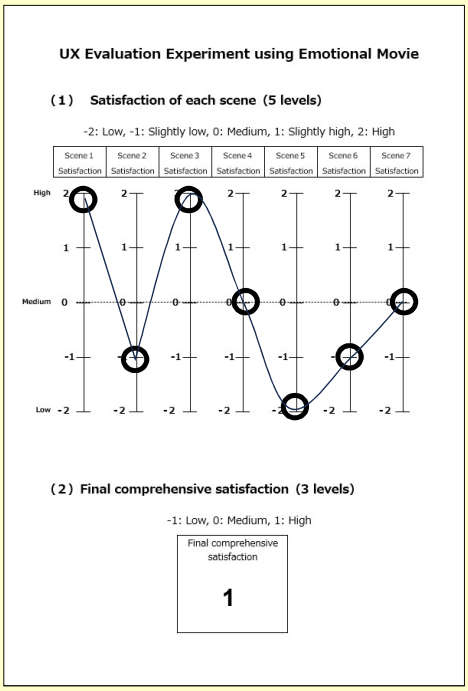


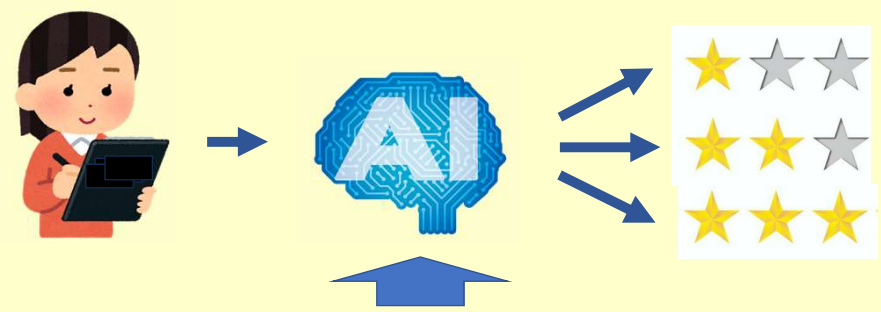
77

Activity: Let's try to write the UX curve.



(9 minutes)





50 sample data (Japanese University students)
Oversampling: Borderline SMOTE
ML algorithm: SVM (polynomial)

Summary of Lecture

- **Biometrics (Behavioral biometrics)**
  - (1) Combination of biological data and dynamic data
  - (2) Combination of biological data and artifacts
  - (3) Combination of biological data and others' biological data

- **Soft biometrics (Usability, UX, VR)**
  - (1) Usability evaluation using objective data (Biological data)
  - (2) UX evaluation using subjective and objective data
  - (3) VR evaluation using subjective and objective data

81