

## **Information List for Poster Submission “Harnessing Vital Sign Vibration Harmonics for Effortless and Inbuilt XR User Authentication”**

### **1. Full bibliographic reference (title, authors, date, venue, etc.) to the paper**

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author = {Zhang, Tianfang and Ji, Qiufan and Akanda, Md Mojibur Rahman Redoy and Ye, Zhengkun and Mahdad, Ahmed Tanvir and Shi, Cong and Wang, Yan and Saxena, Nitesh and Chen, Yingying},  
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### **2. Abstract of the original paper**

Extended Reality (XR) headsets are increasingly serving as repositories for substantial volumes of sensitive data and gateways to web applications. This transition highlights the need for convenient and secure user authentication solutions. Traditional password/PIN-based schemes are ill-suited to the XR's gesture- and voice-based interfaces and are prone to shoulder-surfing attacks. Some recent XR systems incorporate two-factor authentication, but it requires additional operations on a second device (e.g., a smartphone or wearable). In this work, we introduce the first effortless and inbuilt XR user authentication system by leveraging the harmonics of vibrations excited by users' vital signs. The system is transparent to users (no efforts during enrollment and authentication) and requires no additional hardware. The key idea is that vital signs (i.e., breathing and heart beating) naturally generate low-frequency mechanical vibrations, causing human skull to vibrate and produces harmonic signals. When the harmonics pass the human head, they carry rich biometrics associated with the wearer's skull structure and soft tissues, which can be captured by the XR motion sensors. Instead of directly utilizing the vibrations, we extract more reliable biometrics from the ratios among different harmonic frequencies, which capture wearers' unique head and facial attenuation properties and are non-volatile when the periodicity and amplitude of vital signs fluctuate. We further design an adaptive filter to mitigate the body motion distortions in common XR interactions. By adopting advanced deep learning models with the attention mechanism, our system realizes effective and robust authentication across XR scenarios. Evaluations across 10 months, with 52 users and two popular XR headsets, show that our system can accurately authenticate users with over 95% true positive rates and rejects unauthorized users with over 98% true negative rates under various XR scenarios, with biometrics remaining consistent over long-term periods.

### **3. Link/DOI to the published paper**

<https://doi.org/10.1145/3719027.3765060>

# Harnessing Vital Sign Vibration Harmonics for Effortless and Inbuilt

## XR User Authentication



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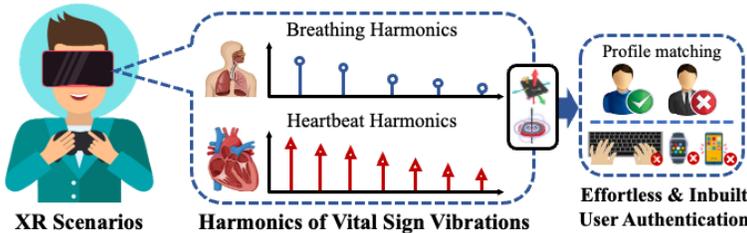
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### Motivation

- Extended Reality (XR) have gained great attention driven by 3D spatial displays and motion tracking
- Sensitive data (e.g., personal accounts, confidential documents) is being migrated from traditional computers to XR headsets
- Existing password-based methods and Two-factor Authentication (2FA) from traditional devices do not align well with XR's unique input interfaces (e.g., no physical keyboards)



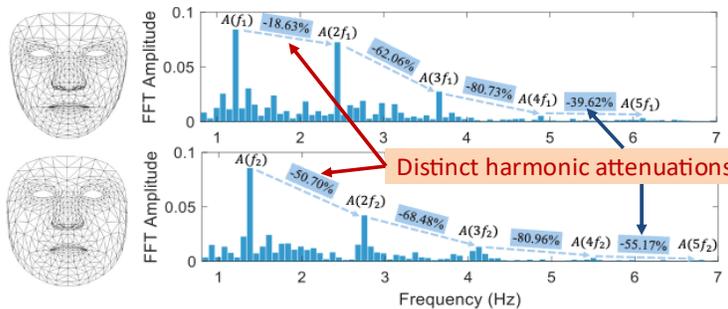
#### Our Idea:

- Leverage vibrations of human's vital signs to authenticate users
- The vital signs produces harmonics (i.e., multiples of the vital sign frequency), capturing the user's head and facial biometrics
- We harness biometrics encoded in vital sign harmonics via sensing with XR inbuilt motion sensors

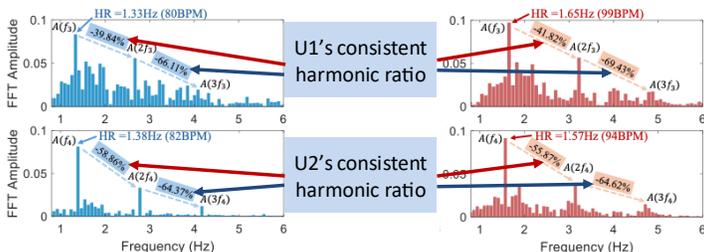
### Preliminary Study

- Vital signs naturally generate low-frequency mechanical vibrations
- Human head acts as a resonant structure and inject harmonic patterns (e.g., attenuations) into the vibrations of vital signs

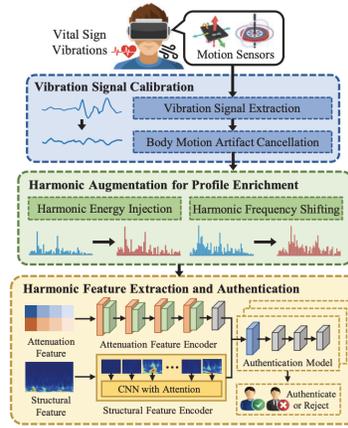
Facial tissues	Density (kg/m <sup>3</sup> )	Elasticity (kPa)	Viscous Ratio (%)
human skull	~ 1.92 × 10 <sup>3</sup>	1.00 × 10 <sup>6</sup> ~ 7.00 × 10 <sup>6</sup>	~ 15%
head bones	~ 1.90 × 10 <sup>3</sup>	1.00 × 10 <sup>6</sup> ~ 5.00 × 10 <sup>6</sup>	~ 20%
brain tissue	~ 1.04 × 10 <sup>3</sup>	0.1 ~ 100	40% ~ 50%
facial skin	~ 1.10 × 10 <sup>3</sup>	1.95 × 10 <sup>4</sup> ~ 8.71 × 10 <sup>4</sup>	30% ~ 60%
facial muscle	~ 1.06 × 10 <sup>3</sup>	6.40 × 10 <sup>2</sup> ~ 1.58 × 10 <sup>3</sup>	18% ~ 22%
fat tissue	~ 0.90 × 10 <sup>3</sup>	5.3 ~ 18.1	45% ~ 60%



- The attenuation ratio across the amplitude of fundamental frequency, first, second harmonic remains stable for the same user



### System Design



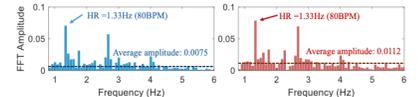
#### 1. Vital Sign Harmonic Calibration

- Adaptive filtering to mitigate body motion artifacts
- Design of Harmonic Attenuation and Structural Features

- Harmonic Features:** Harmonic Amplitude Ratio (HAR), Harmonic Energy Ratio (HER), Total Harmonic Distortion (THD), Harmonic-to-Total Ratio (HTR)
- Structural Features:** Cepstrogram & wavelet features

#### 3. Harmonic Augmentation for Robust Authentication

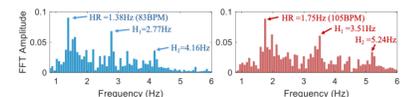
- Simulate the variations in vital sign magnitude and frequency to enrich profiles



(a) Harmonic distribution before and after harmonic energy injection

#### 4. User Authentication

- Attention-based network by combining harmonic and structural features



(b) Harmonic distribution before and after harmonic frequency shifting

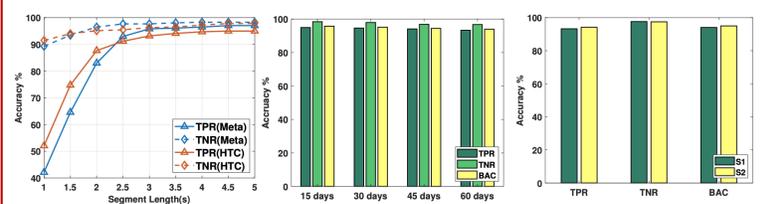
### Experiments and Evaluation Results

- Participants: 52 participants involved aged from 18 to 45
- Two XR Headsets: Meta Quest and HTC Vive Pro Eye
- A prototype is built to evaluate the performance



- Overall Authentication Performance: Average TPR and TNR of more than 96.95% and 98.77% for all participants

- Cost of User Registration: TPR and TNR of more than 95.79% and 97.64% with the frame length of 3 seconds



### Acknowledgement

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