CLAPMETRICS: Decoding Users' Gender and Age Through Smartwatch Gesture Dynamics

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Presentation Overview

Why Age and Gender Estimation?

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Personalized User Experiences

- **Streaming Services**: Platforms like Netflix could recommend age and gender-specific content, such as animated films for younger users or true crime series for adults.

Streaming Services

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- **Health and Fitness Apps**: Exercise recommendations in apps like MyFitnessPal or Strava could adjust based on age—strength training for younger users and flexibility exercises for older ones.

Streaming Services

Fitness App

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- **Health and Fitness Apps**: Exercise recommendations in apps like MyFitnessPal or Strava could adjust based on age—strength training for younger users and flexibility exercises for older ones.
- **News Apps**: News aggregators like Flipboard could suggest content relevant to different demographics, like career advice for younger users and financial planning for older users.

Streaming Services

Fitness App

News

Why Age and Gender Estimation?

Increased Security and Authentication

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- **Healthcare Access Control**: Hospitals and healthcare systems could integrate age and gender checks in wearables to protect patient data and control access to sensitive areas.

Banking Security

Healthcare Access Control

Existing Techniques and Their Limitations

Facial Features

- **Strengths**: High accuracy in controlled environments; widely applicable in consumer and security applications.
- **Limitations**: Sensitive to lighting and angle; privacy concerns; accuracy may degrade with aging. **It is an Intrusive way!**

Virmani, Deepali, Tanu Sharma, and Muskan Garg. "GAPER: gender, age, pose and emotion recognition using deep neural networks." Advances in Electromechanical Technologies: Select Proceedings of TEMT 2019. Springer Singapore, 2020. 287-297.

Existing Techniques and Their Limitations

Fingerprint Analysis

- **Strengths**: Accurate and consistent with unique fingerprint patterns; works well in secure environments.
- **Limitations**:Requires physical contact, which may raise hygiene concerns; age estimation is limited. **It is an Intrusive way!**

Spanier, Assaf B., et al. "Enhancing Fingerprint Forensics: A Comprehensive Study of Gender Classification Based on Advanced Data-Centric AI Approaches and Multi-Database Analysis." Applied Sciences 14.1 (2024): 417.

Voice Analysis

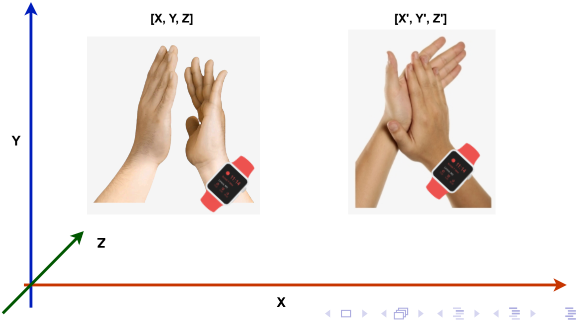
- **Strengths**: Non-intrusive and works with audio data alone; useful in hands-free applications.
- **Limitations**:Accuracy affected by background noise, vocal health, and language dependency.

Foggia, Pasquale, et al. "Identity, Gender, Age, and Emotion Recognition from Speaker Voice with Multi-task Deep Networks for Cognitive Robotics." Cognitive Computation (2024): 1-11.

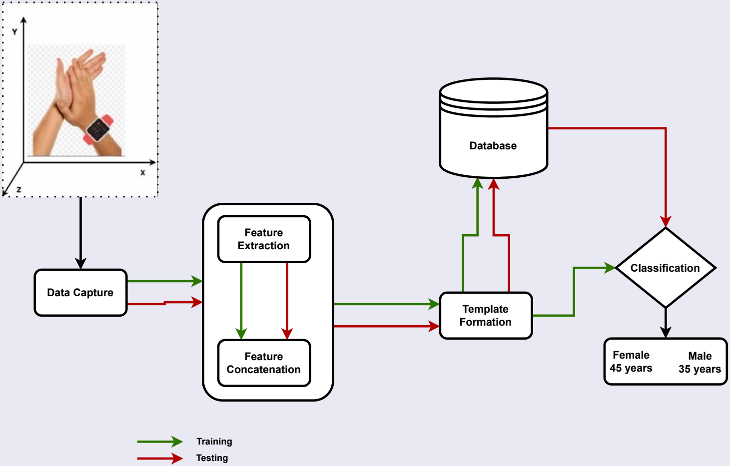
CLAPMETRICS: Decoding Users' Gender and Age Through Smartwatch Gesture Dynamics

Introduction

- **We propose the exploitation of arm's micro-movements generated during the course of clapping action to estimate age and gender of wearer/clapper.**
  - **Strengths**: Completely un-intrusive, accurate, user-friendly, does not require any additional physical contact, ...
  - **Limitations**: Might be too difficult in some scenarios (although, a faint clap would be ok).



Approach

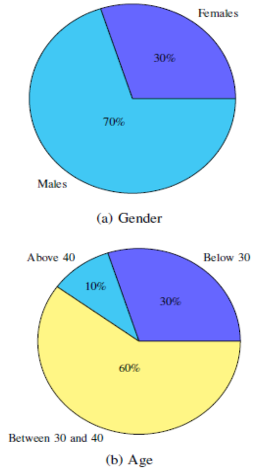

Y
X
Z
Data Capture
Feature Extraction
Feature Concatenation
Template Formation
Database
Classification
Female 45 years
Male 35 years
Training
Testing

ClapMetrics

Data Collection

- **20 participants**
  - **students and researchers**
- **3 body posture**
  - **Sitting, Standing, and Walking**
- **Signup**
  - **100-sec data in each of the posture**
  - **In total, 3000s of data (Used in this paper)**
- **Sign-in**
  - **100-sec data in any of the posture**
  - **In total, 2000s of data**

Subjects



FEATURE EXTRACTION

SENSOR DATA

- **Sensors are 3-dimensional: 4D data from accelerometer and gyroscope**

$$m = \sqrt{sensor[x]^2 + sensor[y]^2 + sensor[z]^2} \tag{1}$$

STATISTICAL FEATURES

- **41 statistical features from each sensor**
  - **Min (4+4), Max (4+4), Mode (4+4), Median (4+4), Mean (4+4), Variance (4+4), Skewness (4+4), Kurtosis (4+4), Correlation (3+3), Abs (3+3), Cosine similarity (3+3)**

Classifier Selection and Optimization

Classifiers

- **BN**: Probabilistic graphical models representing variables and their conditional dependencies.
- **KNN**: Non-parametric method known for simplicity and effectiveness in classification.
- **RF**: Ensemble learning method constructing multiple decision trees for accurate and stable predictions.
- **DNN**: Advanced machine learning classifier, particularly with Convolutional Neural Networks (CNNs).

Parameter Optimization

Classifier	Parameters	Range of Parameters	Best Hyperparameter	Best Validation Accuracy (%)
KNN	*# of neighbors*	1 to 50 (increment=5)	1	(Age: 99.38) (Gender: 96.31)
RF	*# of estimators*	100 to 1000 (increment=100)	200	(Age: 98.20), (Gender: 96.13)
DNN	*num_layers* *num_units* *learning_rate*	2 to 10 (increment=1) 32 to 512 (increment=32) 0.01, 0.001, 0.0001	3 288, 512, 384 0.001	(Age: 96.93) (Gender: 95.70)

Classification Tasks and Data Partitioning

Gender Estimation

- Formulated as a binary classification task: male or female.
- Simplifies the model's decision-making process for focused gender estimation.

Age Estimation

- Treated as a three-class classification problem to capture distinct age groups.
- Tailors classifiers to recognize and differentiate between specific age ranges.

Data Partitioning

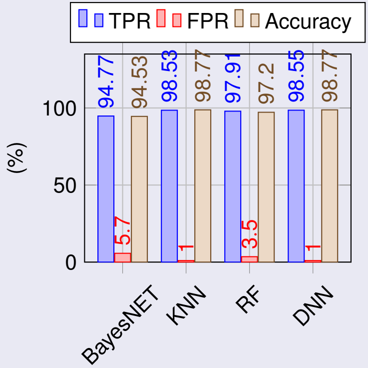
- Dataset split into training (50%) and test (50%) sets for balanced learning and validation.
- Training set further divided: 66% for training, 34% for validation.

Parameter Optimization

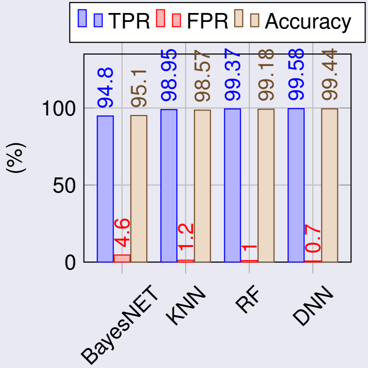
- Conducted exclusively on the training set to fine-tune hyperparameters.
- Optimized parameters applied to classifiers, trained on the full training set, and evaluated on the test set.

Results

Gender Estimation



Age Estimation



DeepClap: Conclusions & Way Forward

Conclusions

- **We propose a user-friendly, un-intrusive, accurate and DNN-powered age and gender estimation using smartwatch**
- **DNN achieves** 98.77% **and** 99.44% **accuracies for gender of age estimation from clapping movements**

Way Forward

- **Final proof-of-the-concept implementation**
- **Performance Analysis (computation, memory, testing time)**
- **Security analysis (random, mimic, etc)**
- **Usability analysis (SUS, etc.)**

Thanks!
Questions?