Using digital archaeology and machine learning to determine sex in finger flutings

Andrea Jalandoni[1], Robert Haubt[2], Calum Farrar[1], Gervase Tuxworth[3], and Zhongyi Zhang[3]

[1]Place, Evolution, Rock Art Heritage Unit, Griffith Centre for Social and Cultural Research;

[2]Australian Research Centre for Human Evolution, Griffith University;

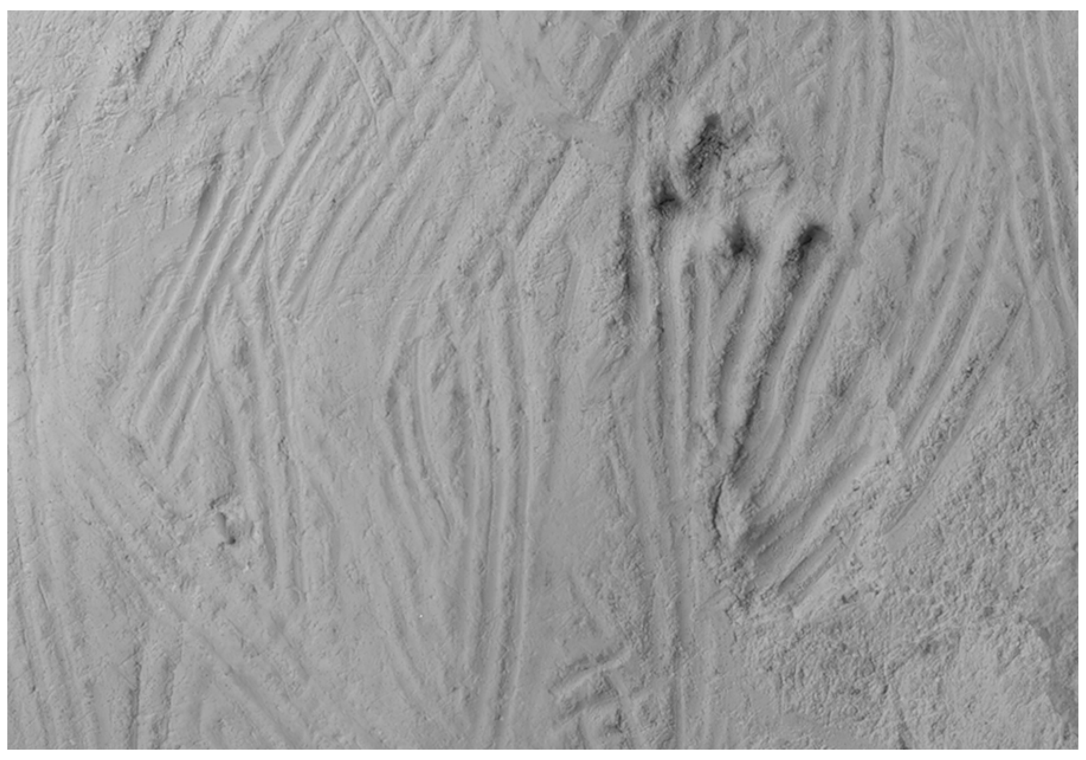
[3]School of Information and Communication Technology, Griffith University

Abstract

One of the earliest and most enigmatic forms of rock art are finger flutings. Previous methods of studying them relied on biometric finger ratios from modern populations to make assumptions about the people who left the flutings—an approach that is both theoretically and methodologically problematic. This study presents a proof-of-concept for a paradigm shift away from error-prone human measurements and controversial theories, toward computational digital archaeology methods using an innovative experimental design that integrates tactile, virtual, and machine learning approaches. We conducted a digital archaeology experiment using tactile and virtual samples from 96 participants. A machine learning model was trained on this known dataset to determine the sex of the individuals who made the flutings. While the virtual dataset lacked sufficiently distinct features for reliable sex classification, the tactile experiment showed promising potential for identifying the sex of fluting artists. However, a larger sample size is needed to support generalization. The significant contribution of this study is the development of a foundational set of methods and materials. We offer a novel digital archaeology framework for data creation, collection, and analysis that is replicable, scalable, and quantifiable.

Problem

Previous research has relied on biometric comparisons with contemporary populations to determine the sex of individuals who created finger flutings. However, this approach is undermined by significant theoretical and methodological limitations, raising concerns about its validity.



Solution

Digital archaeology and machine learning now offer promising tools for analysing tactile and virtual data, potentially enabling deeper insights into prehistoric identity, behaviour, and artistic expression.

Data Capture

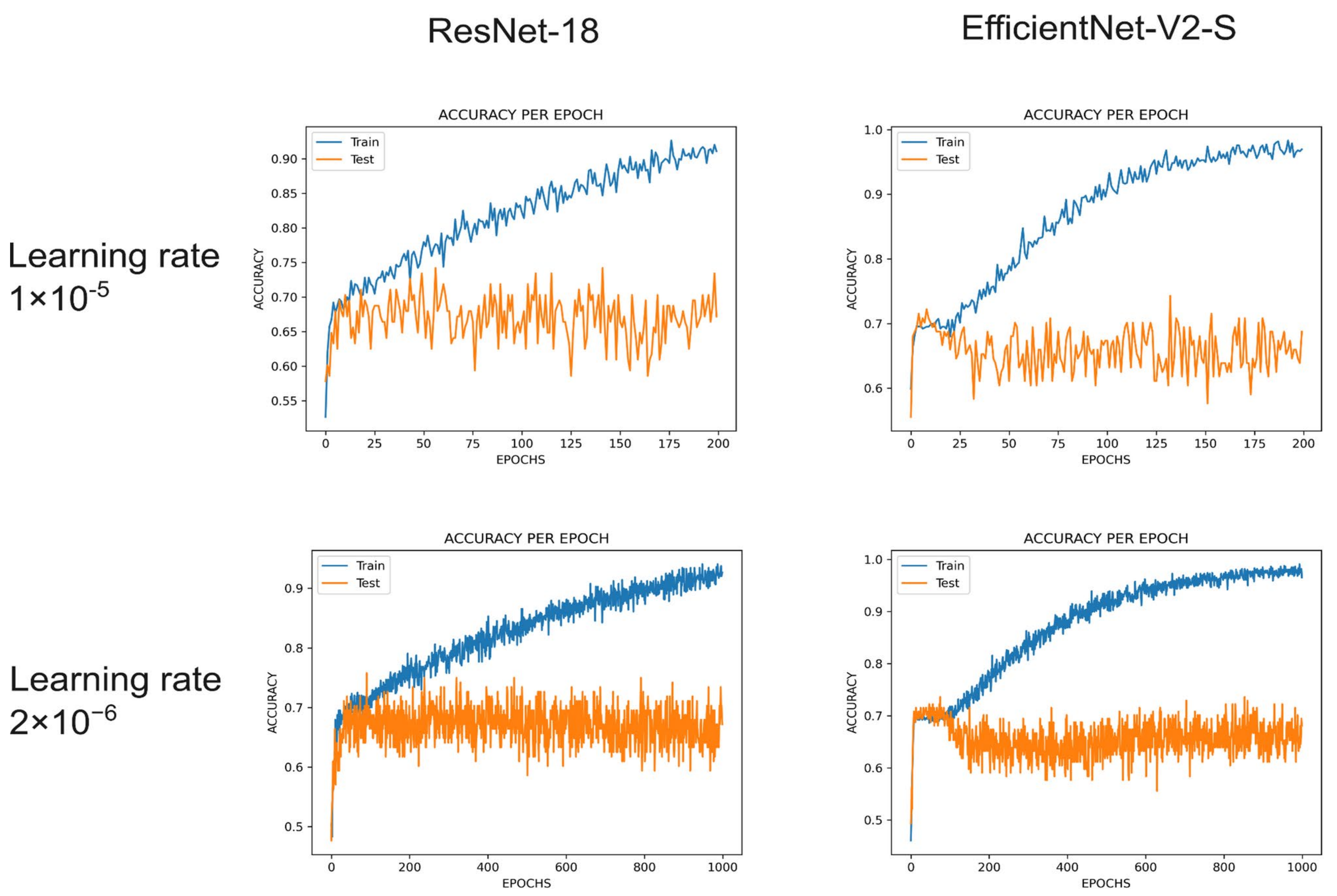
We collected tactile and virtual finger fluting data from 96 adult participants using moonmilk simulacra and a Virtuality Reality (VR) platform. Biometric attributes and fluting images were recorded to train a machine learning model for sex classification. This dual approach enabled scalable, replicable data capture for digital archaeology.

Data Analysis

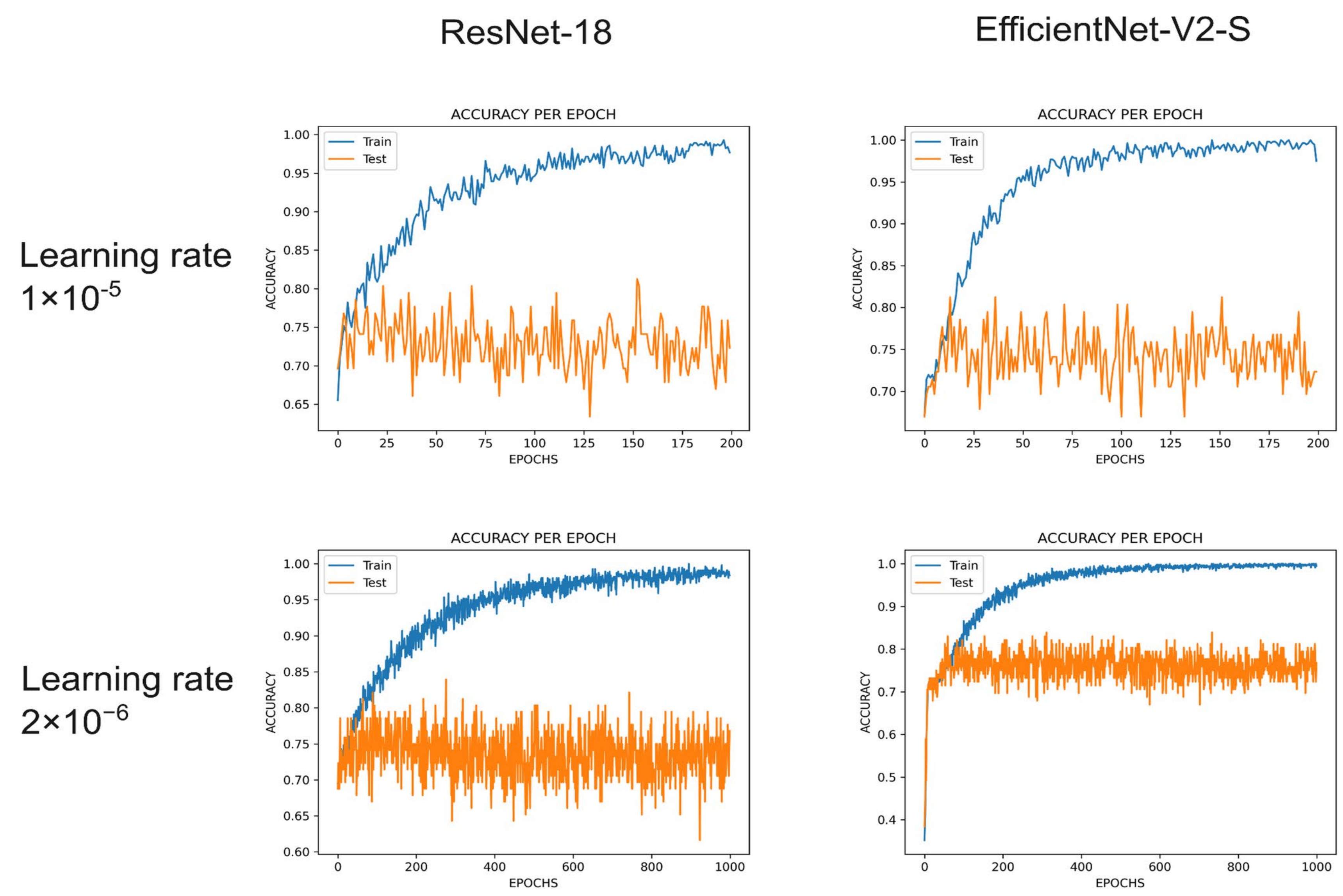
Finger fluting datasets were curated from tactile and VR images. Two CNN models, ResNet-18 and EfficientNet-V2-S, were trained using PyTorch with data augmentation. Performance was evaluated using AUC, accuracy, and F1 score to assess sex classification reliability. All code is publicly available for reproducibility and transparency.

Results

Both models showed signs of overfitting, especially on virtual data where F1 scores were low despite high accuracy. Tactile datasets performed better overall, with ResNet-18 achieving the highest AUC and F1 score. These results suggest tactile data offers more reliable features for sex classification, though generalization remains a challenge.



Training and testing accuracy of ResNet-18 and EfficientNet-V2-S on virtual images using two different learning rates (1×10^{-5} and 2×10^{-6}). The accuracy of both the training and test sets is plotted throughout the training process. Training was conducted for 200 epochs at a learning rate of 1×10^{-5} and 1000 epochs at 2×10^{-6}. The Y-axis represents accuracy, calculated as the number of correct predictions divided by the total number of predictions.



Training and testing accuracy of ResNet-18 and EfficientNet-V2-S on tactile images using two different learning rates (1×10^{-5} and 2×10^{-6}). The accuracy of both the training and test sets is plotted throughout the training process. Training was conducted for 200 epochs at a learning rate of 1×10^{-5} and 1000 epochs at 2×10^{-6}. The Y-axis represents accuracy, calculated as the number of correct predictions divided by the total number of predictions.

Discussion

This study introduced a scalable, reproducible digital archaeology approach that reduces human bias. However, overfitting, limited sample size, lack of external validation, and environmental differences constrain generalizability. Future improvements include expanding datasets, refining VR tools, and exploring ancient biomechanics to enhance archaeological insights and interdisciplinary applications. The toolkit—including a moonmilk simulacrum—lays the groundwork for interdisciplinary research across archaeology, forensics, psychology, and human-computer interaction.

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