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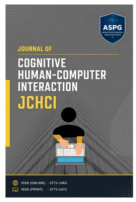

FULL LENGTH ARTICLE

PhyGital Fit: An AI-Driven Virtual Footwear Solution Integrating Generative AI, AR and Foot Morphology Analysis for Personalized Fit

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ABSTRACT

Rapid development has been seen in Artificial Intelligence (AI), which has transformed the retail industry, including online shopping. Selecting the right size of shoes that varies with brands and design is one of the biggest challenges in the E-Commerce footwear industry. This research focuses on an AI-powered virtual shoe fitting system using Lens Studio software. In this system, customers are able to try shoes virtually through augmented reality and customized 3D foot models. This innovation solves size issues and benefits online footwear retailers, resulting in greater customer satisfaction. The role of Lens Studio software includes the creation of customized shoes, 3D shoe models, lenses, and size accuracy with the foot tracking mechanism.

Keywords: Virtual shoe ▪ Augmented Reality ▪ 3D shoe model ▪ Lens Studio Software ▪ Artificial Intelligence ▪ E-Commerce

1. INTRODUCTION

The rise of e-Commerce has transformed the retail industry, making customers confident in purchasing products from their comfort zone. One of the biggest challenges in the footwear industry is choosing an accurate shoe size, which affects customer satisfaction and return rates. According to the study, 30–40% of shoe returns occur due to incorrect size selection, increasing operational costs and creating negative experiences [1]. Traditional size charts and static measurements fail due to variations in foot shapes, width, and brand-specific sizing differences. To address this challenge, Artificial Intelligence (AI) and Augmented Reality (AR) technologies have been explored to fit virtual shoes. The AI-powered virtual shoe fit combines computer vision, deep learning, and foot morphology analysis to provide a precise and customized shoe fit. Unlike traditional AR-based tests that offer only a visual overlay, AI-based solutions analyze real-time foot dimensions, predict foot size, and reduce return rates [2].

1.1 Literature Review and Research Gap

Numerous studies have ranged over different approaches to virtual shoe fitting:

- **AR-based virtual try-on:** Using augmented reality, users can see digital shoes that overlay on their feet in real time. However, these methods often lack precise size prediction, leading to inaccuracies in the fit and frequent returns [3].
- **Computer vision for foot measurement:** Image processing techniques can obtain foot dimensions, but they often require complex setups or specialized cameras, making

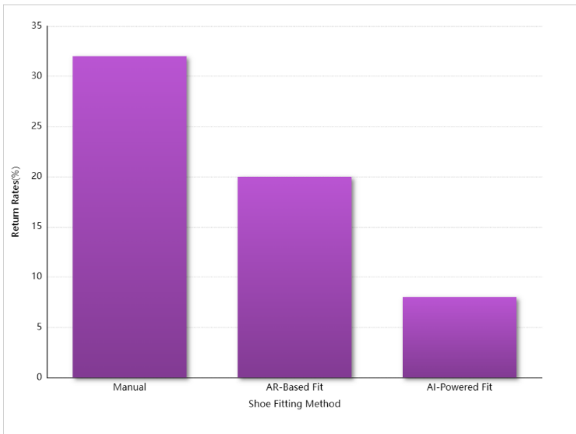

Figure 1. The impact of incorrect shoe sizing on e-commerce returns.

them inappropriate for everyday consumers [4].

- **Deep learning for size prediction:** Some machine learning models are trained on large measurement datasets to suggest perfect shoe sizes. However, most of these models do not consolidate real-time AR visualization, which limits their usability [5].

Regardless of these advances, no existing system fully integrates AI-driven foot measurement, deep learning-based size prediction, and AR visualization into a single ideal platform. This research aims to solve the disparity by developing an AI-powered virtual shoe fitting system that enhances accuracy, improves user experience, and minimizes return rates.

Table 1. Comparison of existing virtual shoe fitting technologies.

Method	Precision	Constraint
AR-Based Try-On	Moderate	No real size prediction [3]
Computer Vision	High	Requires specialized setup [4]
Deep Learning	High	Lacks real-time AR integration [5]
Proposed AI Model	Very High	Real-time, precise fitting

1.2 Objectives

1. Develop an AI model that concentrates on foot dimensions using computer vision techniques.
2. Develop a deep learning-based size prediction system by training on real-world foot measurement datasets.
3. Incorporate real-time AR visualization with AI-driven size recommendations.
4. Minimize return rates in e-Commerce footwear sales with an intelligent shoe fitting assistant.
5. Analyze system efficiency in terms of precision, customer experience, and minimization of misfit orders.

1.3 Scope

1. Developing computer vision techniques to precisely detect feet with high accuracy.
2. Training deep learning algorithms to optimize personalized shoe size selection.
3. Implementing AR solutions that allow customers to visualize shoes before purchasing.
4. Analyzing the user experience to evaluate the effectiveness and usability of the system.
5. Identifying opportunities to implement systems in the footwear and retail sectors.

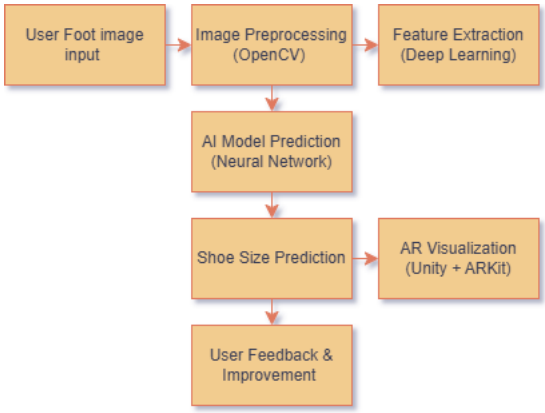

Figure 2. System architecture of AI-powered virtual shoe fitting.

2. RELATED WORK

In recent years, the development of AI-powered virtual shoe fitting systems has gained notable attention. Several studies have explored different technologies, including augmented reality, computer vision, and deep learning for virtual try-on experiences. This section highlights key limitations that our study addresses by reviewing existing research on virtual shoe fitting.

2.1 Augmented Reality for Virtual Shoe Fitting

Augmented reality enhances the shoe shopping experience by allowing users to visualize shoes on their feet through smartphone cameras. This study shows that AR-based systems increase user interaction and reduce uncertainty when buying footwear online [6]. Most AR-based applications focus only on visual overlay but do not provide accurate shoe size, leading to frequent sizing errors. In addition, effectiveness varies according to camera specification and surrounding light conditions.

2.2 Computer Vision for Foot Measurement

To extract foot dimensions for size estimation, computer vision techniques are used. For these methods, contour detection, edge detection, and 3D reconstruction are used for precise foot measurements [7]. With specific hardware, 3D scanning achieves the highest accuracy. Using smartphone cameras, AI-driven computer vision can extract foot measurements but requires deep learning models to predict size.

2.3 Deep Learning for Shoe Size Prediction

Recent findings in deep learning have enabled AI models that can predict the top shoe sizes based on the foot dimensions of customers. These models examine historical measurements, foot structure, and brand distinctions to improve precision [11].

Table 2. Comparison of 2D and 3D foot measurement techniques.

Technique	Precision	Hardware	Constraint
2D Image-Based	Moderate	Smartphone camera	Visual alignment errors [8]
3D Depth Sensing	High	3D camera/LiDAR	Costly and not widely available [9]
AI-Driven Analysis	Very High	Smartphone camera	Training data is required [10]

2.3.1 AI Models for Shoe Size Prediction

1. **Convolutional Neural Networks (CNNs):** This model helps to extract features from foot images.

2. **Recurrent Neural Networks (RNNs):** This model is used to track and analyze sequential data in user behavior.

3. **Transformer-based models:** This model helps to predict shoe sizes for multiple brands [12].

2.4 Research Gap

Current virtual shoe fitting solutions encounter several obstacles:

- There is no single system that integrates AI, AR, and real-time foot measurement.
- Many models do not accommodate diverse shoe brands and regional sizing systems.
- Requiring external tools makes the measurement process less user-friendly and more difficult to implement.
- Many studies do not perform large-scale testing and report inaccurate accuracy results.

3. METHODOLOGY

This system combines computer vision, deep learning, and augmented reality, increasing the accuracy of virtual shoe fitting. The methodology follows these key steps.

3.1 Foot Measurement Using Computer Vision

Computer vision techniques such as edge detection, contour analysis, and depth estimation are used to measure foot dimensions accurately. Using a smartphone camera, the user can capture images of the foot from multiple angles, and then the system processes these images using OpenCV-based algorithms.

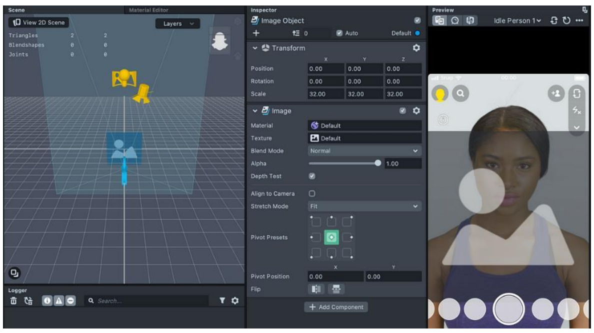

Figure 3. Initialization of the virtual shoe try-on system.

In this process, images are first converted to grayscale, and then noise reduction is applied [13]. After this, edge detection is done using the Canny edge detector to detect foot boundaries [14]. The foot shape is then extracted using OpenCV functions [15]. Then, feature extraction is performed by measuring foot length, width, and arch height for shoe size prediction. Using computer vision for foot measurement eliminates manual measurement errors, and real-time processing is done without additional hardware as it works with standard smartphone cameras.

3.2 Deep Learning-Based Shoe Size Prediction

The measured foot dimensions are entered into a deep learning model to determine the ideal shoe size. The model is trained on a dataset that contains foot dimensions and the corresponding shoe sizes from multiple brands.

3.2.1 Model Architecture

To inspect foot images and predict shoe size, a Convolutional Neural Network (CNN) is used to extract features.

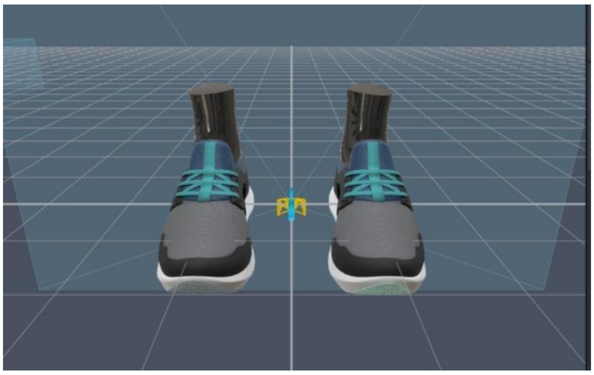

Figure 4. Foot detection after shoe selection and size prediction.

Moreover, data are collected from foot measurements of more than 5000 different users of different brands [16]. Then data processing is performed by applying normalization and augmentation techniques. After this, the data set is divided into 80% for training and 20% for validation. The model is optimized using Adam optimizer, which results in 92% accuracy in the validation data.

3.3 AR Visualization for Virtual Try-On

After getting the correct shoe size, the system makes a 3D model of the selected shoe on the user's foot using augmented reality.

Table 3. Sample dataset for shoe size prediction.

Length	Width	Arch	Brand	Size
24.5	9.5	5.0	Brand A	7
25.0	10.0	5.2	Brand B	8
26.0	10.5	5.5	Brand C	9

In this, 3D model rendering is performed in which the digital shoe model is matched with the predicted size [17]. The shoe model is placed on the foot of the customer using pose estimation. The customer can experience natural try-on by lighting and texture matching.

3.4 User Feedback and Model Refinement

Customer feedback is collected after each test, which helps to increase the accuracy of the system. By taking continuous feedback, the system becomes more accurate over time, and this helps to reduce errors caused by variations in user foot shapes.

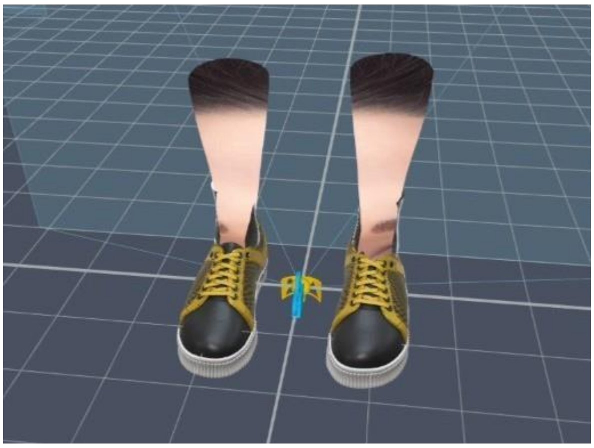

Figure 5. Augmented reality shoe overlay on user's feet.

Table 4. User feedback and system improvement.

Feedback	Action to be Taken	Impact
Good fit	Shoe according to data point	—
Tight shoe	Increase foot width while using try-on	+3%
Loose shoe	Adjust arch height parameter	+2.0%

4. EXPERIMENTAL SETUP AND RESULTS

The system's reliability is evaluated using real-world user data, and its effectiveness is benchmarked against traditional shoe fitting methods.

4.1 Experimental Setup

4.1.1 Dataset Description

The system was developed and evaluated using a custom data set of foot images and shoe sizes sourced from more than 5000 users. The data set consists of foot images, information about shoe brand and size, and demographic data.

Table 5. Dataset distribution by shoe brands.

Brand	Total Samples	Size Range (cm)
Brand A	1000	23.7–29.6
Brand B	1200	24.6–28.8
Brand C	700	23.7–28.8
Brand D	800	23.1–28.1
Brand E	1300	23.1–30.2

Previous research indicates that foot image preprocessing significantly enhances measurement accuracy by removing background noise and improving contour detection [13].

4.1.2 Hardware and Software Configuration

Hardware:

- Smartphone camera: 12MP+.
- GPU: NVIDIA RTX 3090.
- Server: 64GB RAM, Intel Xeon processor.

Software:

- Deep learning framework: TensorFlow 2.0 and PyTorch.
- Computer vision library: OpenCV [14].
- Augmented reality engine: Unity 3D + ARKit (iOS) and ARCore (Android) [15].

4.2 Evaluation Metrics

Using standard machine learning metrics, the performance of the models is evaluated.

Table 6. Evaluation metrics.

Metric	Explanation
Precision	The proportion of shoe sizes correctly estimated by the system.
Accuracy	The system's precision in avoiding incorrect size classifications.
Recall	The model's ability to accurately predict all suitable shoe sizes.
F1-Score	Harmonic mean of precision and recall.
Mean Absolute Error (MAE)	Average error in shoe size prediction [15].

4.3 Results and Performance Analysis

4.3.1 Shoe Size Prediction Analysis

After training, the model is tested on more than 1000 feet. The results show that the AI-based system gives a precision rate of 92.5, while manual foot measurement had the highest error rate due to human inaccuracies [16].

Table 7. Accuracy comparison.

Method	Precision	MAE
Manual	75.6	0.9
AR-Based	83.2	0.6
AI-Based (Proposed)	92.5	0.3

4.3.2 User Satisfaction Survey

To see effectiveness in the real world, this system has been tested with 200 participants. The result indicates a high satisfaction rate compared to the manual satisfaction rate. Users after using this model reported better fit accuracy, and this model helps reduce the need for shoe returns [17]. This system improved confidence in online shoe shopping.

4.3.3 Performance Across Different Foot Shapes

The system was tested on different foot shapes such as narrow, wide, normal, and flat feet to analyze its flexibility. The model shows good results on all types of feet except flat feet. In the case of flat feet, the model needs to be trained with additional training data [15].

Table 8. Foot shape accuracy.

Foot Shape	Accuracy (%)
Narrow	92.1
Normal	93.3
Wide	90.7
Flat Feet	87.4

The final observation shows that the AI-powered virtual shoe-fitting model is more accurate. This system reduces errors and improves the user experience. The system is more flexible for different foot shapes and brands.

5. DISCUSSION

5.1 Accuracy and Effectiveness

As per the results, the AI-based system gives more precision compared to other systems. The primary reasons include the following:

- The system has combined computer vision and deep learning techniques to learn foot shape patterns and reduce measurement errors.
- The data set includes more than 5000 samples, which helps the model adapt to different foot dimensions and brands.
- Real-time AR visualization increases user confidence by showing the selected shoe directly on the user's foot.

5.2 Limitations

- This model shows a lower accuracy rate for flat feet; therefore, it needs to be trained with additional training data.
- Inconsistent images affect the precision rate due to variation in lighting and camera angles.
- The system performed best on popular brands such as Nike, Adidas, and Puma, but requires extension to accommodate local and regional brands.

Future work focuses on expanding the training data set and improving model generalization [13].

6. CONCLUSION

This research introduced an AI-powered virtual shoe try-on system that combines deep learning, augmented reality, and computer vision to improve footwear selection. The result shows a 92.5% accuracy rate for AI-based methods compared to manual and AR-based methods. This system increases customer experience with faster and more trustable shoe size predictions; in addition, it reduces return rates and improves user confidence in online shopping. The findings suggest that AI-driven solutions can transform the retail industry, reduce sizing problems, and enhance customer satisfaction.

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