Exploring The Potential of Digital Twin Technology for Enhancing Online Shopping Experience

Vasileios Efthymiou[1], Anastasios Eleftheriadis[2], Efstathios Iosifidis[3], Panagiotis-Fotios Mavromatis[4], Georgios Tzelalis[5]

[1]Vasileios Efthymiou,ics21035
[2]Anastasios Eleftheriadis,ics22135
[3]Efstathios Iosifidis,iis21027
[4]Pnagiotis-Fotios Mavromatis,ics21073
[5]Georgios Tzelalis,ics21032

Konstantinos E. Psannis
kpsannis@uom.edu.gr

Abstract

Digital twin technology has gained increasing popularity in recent years, and the rise of e-commerce during the COVID-19 pandemic has highlighted the need for a better online shopping experience. This paper proposes the integration of digital twin technology,augmented reality (AR) and e-commerce to create an enhanced shopping experience by providing users with interfaces to physical assets.Specifically,the paper explores the use of digital twin technology and AR to enable customers to try out outfits and shoes online without having to visit a physical store.To achieve this,data will be collected from sensors on physical shoes and clothing,and analyzed using techniques such as 3D model fitting,anthropometrics and machine learning. By using machine learning, simulations can be run on the digital twins to show how the shoe or clothing item will fit on the customer and how it will wear out over a certain period of time.Additionally,the paper examines full body motion capture for re-identification applications for human digital twins.By providing this level of interactivity,the proposed approach has the potential to revolutionize the online shopping experience and address some of the key challenges facing e-commerce businesses.The paper concludes with a discussion of the implications and the potential future developments of the proposed technology.

Keywords: *Digital twin technology,e-commerce,online shopping experience,sensors,machine learning,augmented reality, simulations,interactivity*

1.Introduction

The idea to tackle the problem of online shopping experience arose from the increasing demand for online shopping due to the COVID-19 pandemic. With the closure of physical stores and the need for social distancing, consumers turned to online shopping as a safe alternative. However,one of the challenges with online shopping is that customers are unable to physically try on the clothes or see how the product would look on them.This can result in a less satisfying experience and higher rates of returns. To address this problem, we propose the use of Augmented Reality (AR) technology combined with machine learning algorithms and digital twin technology. By using AR, customers can virtually try on outfits and see how they fit on them, providing a more realistic experience. Furthermore,machine learning algorithms can simulate how shoes will wear out in the future, giving customers an idea of how long the product will last. The use of digital twin technology can further enhance the online shopping experience by creating a virtual replica of the product. This will allow customers to view the product from all angles and even interact with it in a virtual environment. By using digital twin technology, customers can get a more realistic idea of the product before making a purchase decision. For the implementation of this idea, we propose the use of AR development platforms such as Apple's ARKit or Google's ARCore. Machine learning algorithms can also be used to simulate the wear and tear of shoes, using data such as shoe material, usage frequency and terrain. This will require the use of programming languages such as Python and machine learning libraries such as TensorFlow. To implement the digital twin technology, there is the need for a virtual replica of the product using 3D modeling software such as Blender. Data can also be incorporated from the product's physical counterpart, such as size,shape and material. This will allow the digital twin to accurately simulate the product's appearance and characteristics. By combining AR, machine learning, and digital twin technology, we can create a comprehensive online shopping experience that allows customers to virtually try on products, simulate wear and tear and interact with the digital twins. This will not only improve customer satisfaction but also reduce the rate of returns, ultimately benefiting both the customer and the retailer.

This research paper is structured into several distinct parts. After the introduction, we analyze prior research and development conducted by other scholars in the following section. Subsequently, we present and provide analysis of our own opinions on the topic at hand.

To fully explore the potential applications of digital twin technology in e-commerce, our methodology section will be divided into several parts, each of which will be critical to the final development of our proposed idea. Firstly, we will explore the use of digital twins for our products. This will involve creating digital replicas of physical products and using them with machine learning to simulate various scenarios, such as wear and tear over time or different usage patterns. By developing these digital twins, we can gather valuable data about our products and identify areas for improvement.

The next part of our methodology will focus on how we can convert the data from these digital twins into 3D models that users can interact with. This will require a separate software application that can take the data from the digital twin and turn it into a visual representation of the product. This will allow customers to see and examine the product in detail before making a purchase.

In addition, we will explore the potential use of augmented reality (AR) and virtual reality (VR) technology to enable customers to virtually try on the products. By integrating AR/VR technology into the digital twin and 3D modeling process, customers can have a more immersive and interactive shopping experience, which can lead to increased engagement and customer satisfaction.

Finally, we will examine how we can use simulations to predict how the products will wear out over time based on user usage. By running simulations on the digital twin data, we can generate data on product lifespan and identify potential areas for improvement. This will help manufacturers and retailers to create products that are more durable and long-lasting, which can lead to increased customer loyalty and satisfaction.

Throughout our methodology section, we will also consider the findings of other scholars in this area. This will involve analyzing their methodologies, results, and conclusions. By drawing on a range of sources and perspectives, we aim to provide a comprehensive and nuanced understanding of the potential applications of digital twin technology in e-commerce.

2. Methodology

2.1 Digital Twins and Machine Learning

Creating a digital twin of a product involves a few steps, starting with collecting data on the physical characteristics of the product, such as its size, shape, weight and material composition. These data can be gathered through various methods, such as 3D scanning or manual measurements. For further clarification, the simplest photo scanning configuration is a binocular stereo, a configuration of two horizontally or vertically aligned RGB cameras (see Fig.1). The reconstruction is based on the correspondences found on the images and the triangulation. In a 3D scene, point P can be projected onto pixels p1 in the first image and p2 in the second image (as illustrated in Fig. 1). However, it is not possible to determine the corresponding pixel location p2 for a fixed pixel location p1 beforehand. In order to find the location p2, an image block around p1 is matched with the most similar block along the epipolar line l. The difference between the corresponding pixel coordinates, denoted as |p1−p2| (the disparity), is then used to calculate the depth of point P through triangulation. This stereo approach can be applied to more than two cameras by coupling pairs of cameras or by utilizing multi-view-stereo techniques.

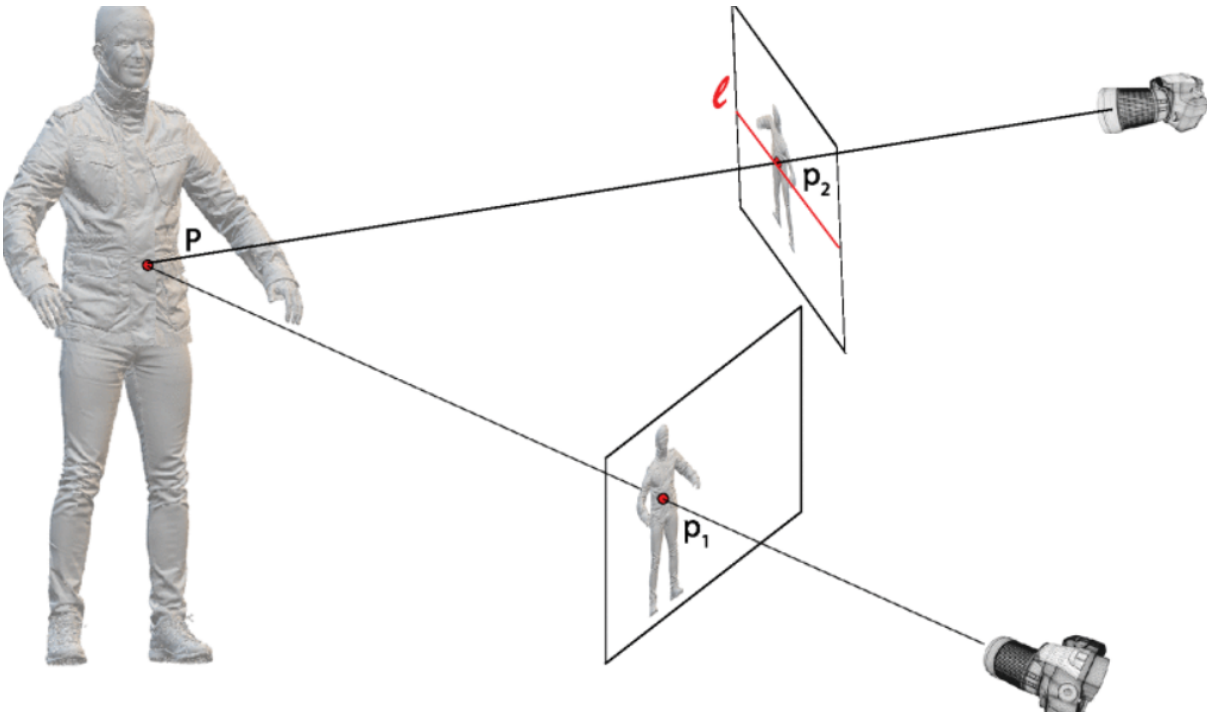

Figure 1: Passive stereo approach

Using the data collected, a digital twin model of the product is developed, which should accurately replicate the physical product and include all relevant details, such as material properties and structural features. To simulate wear and tear on the digital twin, machine learning algorithms can be implemented. These algorithms can be trained on historical data or through simulation to predict how the product will wear over time based on different usage patterns. Simulations are then run to predict how the product will wear over time. For example, simulations can be run to predict how a show will wear out over a year with daily use.Once the simulations are complete, the results are analyzed to identify areas where the product could be improved or optimized. For example, if the simulations show that a particular material is prone to cracking under heavy use, the manufacturer could look into alternative materials or reinforcement techniques. More specifically, the simulations can run by using machine learning models trained on process-based model (PBM) input/output data. This can happen by implementing the following steps:

1. Define the time horizon for predictions and retain only the necessary data.
2. Choose an appropriate aggregation level for the retained data to allow the ML model to make predictions even when high-resolution data are not available.
3. Generate input combinations for the model by defining a hyperspace of input variables. This can be done through a full factorial design or by retaining physically consistent combinations.
4. Reduce the number of input/output datastreams of the PBM to reduce data requirements for the model, based on domain knowledge or feature selection procedures.
5. Develop one or more ML models using the data resulting from the previous steps.

Evaluation of the ML models is crucial to ensure their usefulness for operational/tactical decision making. To assess the predictive capacity of the models, we can compare their errors with a threshold based on domain expertise. Generalization capacity can be tested by examining model performance at both sampled and unsampled locations. The appropriate training data size of the models can also be determined by testing models of different scales with different amounts of data.
Based on the insights gained from the simulations and the analysis, the digital twin model can be updated and the machine learning algorithms can be refined to improve the accuracy of the simulations. So, the proposed algorithm is a hybrid model combining genetic algorithm and linear regression. The genetic algorithm employs biologically inspired operators (mutation, crossover, and selection) and considers all aspects of the data simulation. The linear regression algorithm is used to adjust the data from the genetic algorithm, ensuring accurate results in the simulations.This iterative process can continue until the simulations accurately reflect the real-world wear and tear of the product.By following this methodology, manufacturers and retailers can gain valuable insights into how their products will wear over time, and identify areas of improvement. This can lead to the creation of more durable and long lasting products, which can increase customer satisfaction and loyalty. However, by integrating all the technologies described above into a software program, customers can now visualize how a product will wear and tear over time based on their intended usage. For instance, a customer interested in purchasing a pair of running shoes can input their intended usage (rock trail running, dusty environment etc.) and their foot measurements and the software utilizing a 3D model of the shoe can display how that specific shoe will wear and tear for that specific customer. This enables customers to make informed decisions about which product will best suit their needs, based on an accurate representation of how the product will hold up over time.

2.2 3D Modeling

The creation of a 3D model for AR/VR applications can be approached from two main perspectives: working with a 2D image or a physical object.In the case of a 2D image, photogrammetry techniques can be employed. Multiple high-quality photographs of the object from various angles are captured, ensuring appropriate lighting and capturing intricate details. Photogrammetry software, such as Agisoft Metashape, RealityCapture, or Autodesk ReCap, can then process these images and generate a 3D model.Alternatively, if working with a physical object, 3D scanning techniques are utilized. Various technologies, such as laser scanners, structured light scanners, or depth-sensing cameras, are used to capture the object's shape. Specific hardware options include the Einscan series from Shining 3D, Artec 3D scanners, or the Microsoft Kinect. These scanning devices directly produce a 3D model

based on the captured data.Following the acquisition of the initial 3D model, further refinement is often necessary. This involves using 3D modeling software, such as Autodesk Maya, Blender, or ZBrush, to enhance the model's quality. The refinement process includes tasks like removing imperfections, optimizing the model's topology, and preparing it for optimal performance in AR/VR applications.
To enhance visual realism, textures and colors can be applied to the model using UV mapping techniques. This involves unwrapping the model's surfaces and assigning texture coordinates to enable accurate application of textures.Upon completion, the final 3D model is exported in a compatible format suitable for the intended AR/VR platform. Common formats include FBX, OBJ, or glTF/glb. It is crucial to ensure that the chosen file format and size adhere to the requirements of the specific AR/VR software or platform being utilized.Finally, the 3D model is integrated into the AR/VR development environment. This involves importing the model into appropriate software or game engines, such as Unity, Unreal Engine, or dedicated AR/VR development frameworks. These tools provide the necessary capabilities to incorporate and utilize the 3D models effectively within the AR/VR application.

2.3 AR/VR Implementation

AR/VR technology has revolutionized the way users and companies interact with products, particularly in the context of mixed reality. In this immersive environment, users can virtually interact with various products like shoes or t-shirts, allowing them to try them on and assess their fit without the need for a physical presence. Through the integration of accurate 3D models and augmented reality overlays, users can visualize how the product would look and feel on them, making informed purchase decisions and reducing the likelihood of returns due to sizing issues. By re-engineering IKEA's technologies and utilizing AR platforms like ARKit or ARCore, the foundation is laid for the development of an AR application specifically designed for virtual try-ons and product adjustments in the fashion industry. AR platforms provide a foundation for developing AR applications by offering robust tracking capabilities, object recognition, and spatial mapping. These features are essential for accurately placing virtual objects in real-world environments and ensuring their stability and alignment. Additionally, the AR platform can provide tools for users to assess the fit and look of the virtual clothing items. This may involve incorporating features such as dynamic fabric simulation, realistic lighting effects, and accurate representation of textures. In this case, users can experiment with different styles, colors, and customization options, tailoring the product to their preferences and gaining a personalized shopping experience. Similarly, companies can leverage AR technologies to benefit their product development and testing processes. By utilizing AR/VR applications, companies can virtually simulate the appearance and functionality of a product without the need to physically produce multiple prototypes. This streamlines the design iteration process, reduces costs, and allows for quick adjustments to the product based on user feedback or market demands. Companies can visualize and evaluate the product's aesthetics, functionality, and overall performance, ensuring that it meets their design goals before committing to physical production. AR/VR technologies empower companies to optimize their product development cycles and deliver innovative and high-quality products to the market more efficiently.

Compatibility/Comparison:

Model	Complexity	Needed programming /setup	Latency	Resources	Proposed Idea Compatibility
Hybrid AI Algorithm	High	High	Medium	Low	High
RGB cameras	Low	Medium	Low	Medium	High
PBM ML Model	Medium	High	Medium	Medium	High
ARKit-IKEA AR Software	High	High	Medium	High	High
Reality Capture	High	Low	Medium	Medium	High

Figure 2: Comparison of proposed mechanisms and applications

3. Results

This paper presents a theoretical proposal without any empirical results for examination. As a novel and innovative idea, there are currently no similar papers available online to compare with in this field. The data used in this paper was gathered from existing literature on digital twins, 3D modeling, machine learning, and AR/VR applications in various technological sectors. These sources were combined to develop the proposed technology that can potentially be implemented in real-world scenarios

References:

1.Rogelio Gamez Diaz,Qingtian Yu,Yezhe Ding,Fedwa Laamarti,Abdulmotaleb El Saddik (2020). Digital Twin Coaching for Physical Activities: A Survey

2.A.Levers,Konstantin Vikhorev,David Bowman,Lynn Dwyer,S.Purdie (2021). Transforming digital twins into digital products that thrive in the real world.

3.Tolga Erol,Arif Furkan Mendi,Dilara Dogan (2020). Digital Transformation Revolution with Digital Twin Technology

4.Sudhakar Sengan,Kailash Kumar,Subramaniyaswamy V.,Logesh R. (2022). Cost-effective and efficient 3D human model creation and re-identification application for human digital twins

5.Y. Siriwardhana, P.Porambage,M.Liyanage,M.Ylianttila (2021). A survey on Mobile Augmented Reality With 5G Mobile Edge Computing: Architectures,Applications, and Technical Aspects

6.E.S.Goh,M.S.Sunar,A.W.Ismail (2019). 3D Object Manipulation Techniques in Handheld Mobile Augmented Reality Interface: A Review

7.OpenAI.(n.d.). ChatGPT.Retrieved from https://beta.openai.com/docs/guides/chat-gpt/

8.H.Ahmadi,A.Nag,Z.Khar,K.Sayrafian and S.Rahardja (2021). Networked Twins and Twins of Networks: An Overview on the Relationship Between Digital Twins and 6G.

9.Paul Almasan (2022): Digital Twin Network: Opportunities and Challenges

10.Jun-Phil Uhm,Sanghoom Kim,Chanwook Do,Hyun-Woo Lee (2022). How augmented reality (AR) experience affects purchase intention in sport E-commerce: Roles of perceived diagnosticity, psychological distance, and perceived risks.
11.K. Bartol, D. Bojanić, T. Petković and T. Pribanić (2021). A Review of Body Measurement Using 3D Scanning
12.Christos Pylianidis, Val Snow, Hiske Overweg, Sjoukje Osinga, John Kean, Ioannis N. Athanasiadis (2022). Simulation-assisted machine learning for operational digital twins