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Augmented Reality for Enhanced Performance in Footwear Shopping Applications: A Comparative Analysis

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Abstract— *The Sri Lankan footwear industry has sustained for a very long time and has been successful in serving the local market. One of the biggest industries today struggling with e-business models is the footwear sector. The researcher has gone through the existing footwear-selling applications. During the procedure of analyzing the problem, the researcher conducted interviews with footwear sellers and buyers and distributed questionnaires to them. The key obstacle that people have encountered when making online purchases is finding the best footwear product that suits their requirements. This means that it can be difficult to imagine how shoes will appear on their feet and how they will feel when they are worn. The researcher found out that augmented reality can quickly resolve this problem. Augmented reality is a field of image processing that deals with the combination of the real world and virtual environment. Researchers investigated through ARCore, ARKit, and DeepAR for 3D model visualization. In mobile app development, DeepAR has important features for 3D model rendering such as plane detection, point detection, light estimation, 3D object tracking, background segmentation, and object placement. Therefore, the researcher has proposed DeepAR technology for footwear visualization. Users will be able to accurately visualize how the footwear will look on their feet in real time. Finally, the researcher proposes a mobile application that would help customers who made direct online shoe purchases by letting them virtually see how the shoes would look once they were worn. To increase the profitability of the current footwear industry, the proposed system will give greater support.*

Keywords— **Deep Augmented Reality, Footwear Shopping, Virtual Shoe-Try-On**

I. INTRODUCTION

The footwear industry is a huge industry that makes revenues of nearly US$500 million per year and is expected to grow annually by 6.45% (Statista, n.d.). The COVID-19 pandemic has sped up the transition to a more digital world. (UNCTAD, 2020). Many footwear companies followed the trend and started to engage with various kinds of websites & applications to sell their products to customers. When going through the current applications researcher wanted to check whether is there any problem with online shoe shopping or not. So, the

researcher has surveyed to get more suggestions from other users of online and in-store shoe shops. It shows that there are some real problems in online shoe shops and available platforms.

When selling shoes on online platforms, the purchasers can't check the fit and feel as when they are doing in physical stores. The main aim of this research was to, find out the challenges & problems faced by the purchasers and sellers in the current online shoe shopping industry and give them a solution by applying best matching technologies after identifying and

analyzing the related technologies. The research objectives were,

1. Analyzing the problems & challenges faced by users in the footwear industry.
2. Analyzing the users' opinions to enhance the performance of the current online shoe-selling platforms.
3. Identifying and analyzing the performances of the matching technologies which could be applied to solve problems and improve the effectiveness of the online shoe-selling platforms.

Augmented reality (AR) is a technology that allows users to experience a digital overlay on top of the real world. In the footwear industry, AR can be used in a variety of ways, such as allowing customers to try on shoes virtually before purchasing and providing interactive and engaging product displays. This technology has the potential to revolutionize the way people shop for shoes, offering a more convenient and immersive experience. With AR, customers can easily see how a shoe will look and fit on their own feet without even having to visit a store. So, the hypothesis of the research was that augmented reality will be more supportable to enhance the effectiveness of online shoe-selling applications.

II. LITERATURE REVIEW

Covid 19 pandemic has stimulated the improvement of online businesses. Most of the e-commerce websites and mobile applications have been developed just because the physical stores have limitations to reach purchasers. With these online platforms, most problems that were there with physical shopping got solved. But still, some areas and industries seem to have problems reaching their customers effectively.

So, in this section researcher discussed the first research objective of this research. That is analyzing the performances and problems of the current footwear selling applications and how the footwear applications evolved in the past years. The researcher used research papers and various relevant websites to gather information on shoe-shopping applications. The researcher has classified referred details under three sub-topics to ease the understandability.

A. Traditional Online Shoe Shopping

The current footwear market's traditional sector is quite reluctant to use new technologies. Small and medium-sized businesses (SMEs) dominate the industry, and there are only a few high-end large-scale brands run across the country. Since the majority are small and medium-sized sellers, they cannot afford the pricey, high computational capacity equipment, and technologies to find a solution. In general, these businesses use common, inexpensive hardware and software such as social media for promoting and simple POS systems for billing (Jimeno-Morenilla, Sánchez-Romero, and Salas-Pérez, 2013). The traditional in-store shoe shopping method is still popular and used by the majority. Countries and areas which are still not tech-savvy are using traditional in-store shopping methods. And there is a tendency to be used in-store methods by technology-friendly people too. It's because shoes are not like other items that can be used by just buying them. Footwear gives a feeling and emotions to the users. People like to feel new, beautiful, and special with their shoes (Bizen et al., 2021). The reason behind using traditional methods even when they are fully accessible to online platforms might be this. As this article mentioned shoe lovers want to feel it and see it before buying.

B. Different Technologies Used

To find a solution to the problem found in the footwear industry, researchers have to analyze the different technologies that have been adopted by similar systems. The ITIA of CNR has developed a system called the Magic Mirror that enables the user to virtually try on shoes before purchasing or ordering them when paired with advanced footwear technology for measurement. To do this, the user used some unique "socks" with painted-on, spherical infrared reflective markers that act as a monitoring system for Magic Mirror, which is an LCD screen that processes data from the electronic library and inputs data from the client to determine whether the model selected is approved, to identify and mirror the movement patterns of the customer. Because of the need for some improvements to systems like the Magic Mirror or Cisco's retail fitting room, augmented reality has not yet fully entered the industrial market for advertising applications (Carmigniani et al., 2010).

Figure 1. Magic Mirror System

This research (Jimeno-Morenilla, Sánchez-Romero, and Salas-Pérez, 2013), mentioned that to simulate how human eyes perceive the world, stereoscopy uses two images of a single scene taken from different perspectives to enhance or create the illusion of depth.

The offset from the alleged location of the camera, which is supposed to capture a specific scene from both the left as well as right viewpoints, must then be determined. Although it is well recognized in the field of computer vision, this calculation is not simple because this offset will also indicate a variation in the angle of vision occurrence on the scene. Based on the widely used footwear manufacturing and design software 3D+1, a stereoscopic vision system has been created. With the help of this software, models can be modified and rendered realistically to create any type of footwear. This one is novel in that it separates recognition from rendering by using two cameras as opposed to one.

Systems using mirror metaphors in augmented reality can be divided into reflective half-mirror displays and mirror displays which can be seen through videos. Both systems have unique traits and different complexity levels in their application fields. The system configuration for an introspective half-mirrored display-based augmented reality prototype system is presented in this paper. And also offer calibration in a two-phase technique that makes use of an additional camera for the setup. Three system error sources were specified. They conducted several experiments to analyze the registration errors (Jang et al., 2014).

A system for assessing footwear design using industry-standard depth-sensing methods is presented in this paper (Yang, Yang, and Chu, 2014). Users of the system can virtually try on 3D shoe models while viewing a live stream in a 3d virtual environment. A two-stage target detection algorithm was developed to accurately align shoe models to moving feet during the try-on process. Color markings on the customer's foot allowed for markerless tracking. The tracking was driven by the iterative nearest approach (ICP) method, which overlaid the recorded depth information and standardized curricula foot models. The ICP-based tracking method, however, was unable to provide precise position recognition when the foot moved quickly. The ICP computation convergence rate was accelerated, and fewer data points were needed to register shape by snipping the model with an immediate camera angle.

C. AR-Based Shoe Applications and Systems

While referring to research papers and articles, the researcher identified that most of the systems have tried to use augmented reality technology to find a solution to footwear experiencing problems. The following is the summary of the referred articles.

Users must evaluate and offer suggestions on their design as quickly as possible (Luh et al., 2012). For products like clothing and shoes that are in close contact with people, this is crucial. This module is an ARToolKitsTM-implemented Unity3DTM add-on. For creating augmented reality, there is a software library available under the open-source label ARToolKitsTM. In these applications, actual imagery is overlaid with digital imagery. Real-time object tracking capabilities provided by this library make it simple to build a variety of augmented reality applications. The tracking features of the ARToolKitsTM determine the precise camera position and direction to physical points of reference in real time. However, a significant restriction is that these signs

must typically be located on a plane or another planar object. The lack of satisfactory precision, accuracy, and tracking robustness of horizontal indicators on curved objects prevents virtual shoe try-on.

Heavy computations are required to recognize human feet inside a video stream and accurately estimate their 3D positions. The user experience may be negatively impacted by a noticeable delay in fast foot motion when using a commercial RGB-D camera. This paper introduces a cloud service framework that implements a network-based virtual shoe try-on in augmented reality. Users decide which shoe model they would like to try on and post a cloud-based video clip of their feet moving. In a brand-new clip created in the cloud, users can see themselves trying on the shoe models while moving through the clip (Chu et al., 2019). The researcher found that the majority of virtual clothing and shoe try-on applications use video streams to illustrate the design outcome. Virtual shoe try-on technology as it stands today still has limits in terms of application. First off, to demonstrate the try-on process, the majority of earlier augmented reality applications used special equipment like a magic mirror or a large display device. Such equipment is not only expensive but also out of reach for the majority of consumers, especially in the growing online market.

The best-augmented reality technique for building a virtual shoe try-on system would likely be marker-based AR. In marker-based AR, the user holds up a marker or object (feet) to the camera, and the AR system uses the marker as a reference point to display the virtual shoes on the user's feet. This technique allows for the precise placement of the virtual shoes on the user's feet and provides a realistic experience for the user. DeepAR is a machine learning algorithm that can be used to generate high-quality, photorealistic images of virtual objects in augmented reality (AR) applications. In the context of a virtual shoe try-on system, DeepAR could be used to generate realistic-looking virtual shoes that can be accurately placed on the user's feet in the AR environment. This could provide a more immersive and engaging experience for the user, allowing them to see how the shoes would look on their feet in real life. However, it should be noted that DeepAR is just one of many possible algorithms that could be used for this purpose. Other algorithms, such as ARCore or ARKit, could also be used to generate virtual shoe images for a virtual try-on system (Ramne, n.d.).

D. Customer Perception Towards AR

Hence the researcher found that AR is the best existing technology that can use to solve problems in the footwear industry and studied more about the customer perception towards augmented reality.

The project (Stoyanova et al., 2015) is primarily concerned with whether AR advertising gives the advertised product any additional benefits, such as a more positive attitude or impulses of a stronger purchase. The relationship between AR advertising and advertising effectiveness must be understood to determine whether interactions with another system have an impact. Overall, the findings show that there are distinctions between the tested systems, especially between the AR and interactive options. In terms of technology, both marker-based & markerless systems fall under the category of augmented reality, and when used in combination, they outperform purely interactive systems. Additionally, the prototype system in the study only used one product from one brand. Perhaps a different product category or a system that allows users to select from a wider range of brands should give different output. In this paper, the researcher mentioned that AR in a virtual try-on setting might cut down on product returns. The ability of AR technology in a virtual try-on setting to enhance information helps customers feel more confident about their choice. Using augmented reality as a virtual try-on tool in retail would offer features like playfulness and informativeness that could enhance the customer experience. One benefit of augmented reality is that it satisfies consumers' growing desire for personalization, with an increasing variety of brands allowing customers to select specific features with their product designs. The users' capacity to envision the finished product during the design process. Before a purchase, AR may also improve how psychological ownership is perceived by consumers (Romano, Sands, and Pallant, 2020).

This study looks at correlations between users' continued use of the augmented reality virtual shoe-try-on function and their perceptions of intrinsic value& interactivity. Customers who have utilized the POIZON APP's virtual shoes serve as the research object and the POIZON APP serves as the research carrier. This study contributes in several ways, one of which is that it tends to suggest how consumers' perspectives of perceived interactivity and intrinsic value affect their willingness to continue using AR virtual shoe-trying feature when they use the AR APP (perceived playfulness and split into aesthetics). Perceived interactivity will influence the consumers' intentions and attitudes through intrinsic value. However, perceived responsiveness has a more powerful influence on perceived playfulness and aesthetics, respectively, than perceived control does in the sense of this study's topic as well as model (Jiang et al., 2021).

III. Methodology

It is significantly more productive to utilize the research onion model for this study for a clearer research technique. The research's guiding principle is to discover the difficulties that footwear vendors and purchasers experience and to provide them with a solution by utilizing foot gesture recognition techniques.

The researcher employed both quantitative and qualitative research methods. The first objective of this study was to determine the strengths and limitations of current footwear shopping applications. As mentioned in the previous section researcher has used research papers, journal articles, and web articles.

The second objective of the research was to analyze the users' opinions to enhance the online footwear shopping experience. The researcher chose a certain group of persons for the data gathering with that goal in mind. The target audience was Sri Lankan shoe purchasers and vendors. The researcher once made some observations about the situation

and collected some thoughts from customers and sellers by personally conversing with them at shoe stores. The researcher believed that a mobile survey was the best method for gathering information from the target audience. After that, the researcher carried out a mobile survey among that particular set of people.

The third objective of the research was to analyze the performance of the foot gesture recognition algorithms which can be applied to enhance the effectiveness of the online shoe shopping system.

As a result, the researcher employed a positivist philosophy with a deductive approach when conducting the research. In order to identify underlying reasons and create future predictions about individual and organizational transformation, the researcher used an interactive exploration technique that blends collaboration in solving problems with data-driven collaboration analysis. The ethnographic approach acknowledges the clients' backgrounds, customs, way of life, behavior, shared differences, and varied perspectives. In this case, a cross-sectional time frame was chosen to conduct the research.

A. Sample Population

The population of this research gathered through a questionnaire was selected normally from the people who are engaging in online footwear shopping. Among the identified 87 sample population consisting of 18 sellers and 69 shoe buyers were elaborate to give their responses for the survey.

B. Data Collection

87 people who had been chosen in advance were given questionnaires to complete in a survey. The researcher also referenced 20 other research articles, journals, and websites. This was done to collect data very precisely to increase the potency of the research's findings.

IV. Results & Analysis

As this study concentrated on the actual usage of online shoe shopping, the results mentioned below are based on the questionnaire that was delivered to the targeted population. Here researcher mentioned all the responses to the questionnaire that was conducted.

A. Social and Demographic Data Are you a shoe vendor or a purchaser?

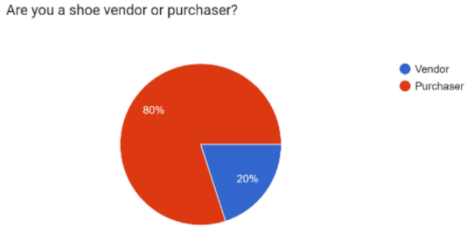

Figure 2. Role of the respondent

Analysis and Interpretation: As depicted in Figure 2, of the 87 respondents, 80% were respondents who are willing to buy shoes, and 20% were respondents who sell shoes. The researcher tried their best to gain more responses from sellers too. Because sellers have more experience in the field of footwear selling than buyers who are buying shoes from time to time.

B. Confirmation Statements

- Confirmation Statement 1

  Are you interested in searching for shoe products that are suitable for you?

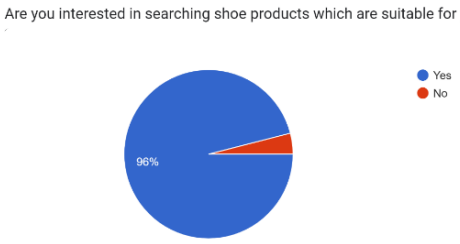

Figure 3. Preference toward Shoe Shopping

Analysis and Interpretation: Figure 3 displays the sample population's responses to Confirmation Statement 1; 96% of respondents indicated that they agreed with the statement.

- Confirmation Statement 2

  What are the methods you are using for shopping the shoe products?

Figure 4. Method Using for Shoe Shopping

Analysis and Interpretation: Figure 4 shows the responses for statement 2 and most of the respondents (68%) have mentioned that they are using physical shops for their footwear needs. Only 32% of the sample population is using online platforms for their footwear needs. This shows that most people are still not interested in online shopping platforms.

- Confirmation Statement 3

  Are you satisfied with the applications which are available for online shoe shopping?

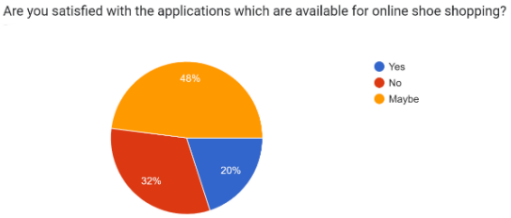

Figure 5. Satisfaction with Current Applications

Analysis and Interpretation: Figure 5 displays the sample population's responses to confirmation statement 3 and most of the respondents have selected “maybe” with the statement. And another 32% of the population seems not satisfied with the available applications. Only 20% of the respondents are satisfied with the existing applications.

- Confirmation Statement 4

Would you like to see how footwear fit & look before buying it through online platforms?

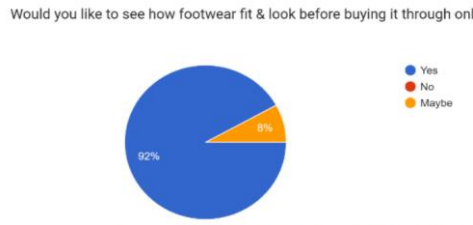

Figure 6. Opinion on Real-Time Preview

Most of the respondents agreed with the statement by giving 92% responses to 'yes' and 8% to 'maybe'. There isn't any no opinion on this question. By investigating these results, currently users are suffered when purchasing shoes from current online shopping applications because they cannot have the tactical experience. Because most of the existing shoe-shopping applications don't give a proper item preview. The main opinion of the customer is to have a proper preview before buying the product.

C. Extant Systems

What are the challenges you faced in physical shoe shopping?

Figure 7. Challenges of Physical Shopping

Analysis and Interpretation: The chart shows the responses of the sample population regarding challenges faced by users for physical shoe shopping. Time wastage and difficulty of going through all the products are the most ticked answers. Both of them have 68% of the results. It proves that even though most of the purchasers are using physical stores, they get it as a time waste, and they have a problem in selecting shoe products. And sometimes they have to face confusion with the ideas given by the shoppers. Independent decision-making is hard when using physical shopping methods in Sri Lanka.

What are the difficulties you faced in using those applications for online shoe shopping?

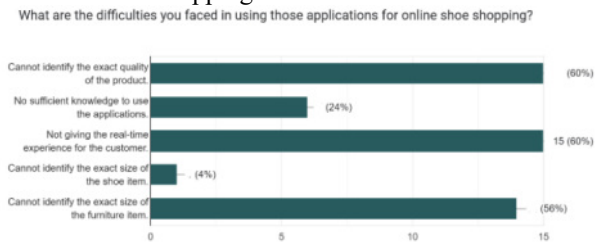

Figure 8. Difficulties of Online Shoe Shopping

Analysis and Interpretation: The chart shows the responses to the difficulties faced by the sample population. The highest percentage mentioned here is 60% for 'Cannot identify the exact quality of the product' and 'Not giving the real-time experience for the users. Both of these statements were key issues in the literature that the researcher referred to. Hence these statements were used as options in the questionnaire. Both literature and survey results are tallied here. Purchasers want to experience the product properly before buying the product. The researcher noted this as a key point to consider when developing a solution.

What is the most favorable application for searching shoe products to take real-time experience?

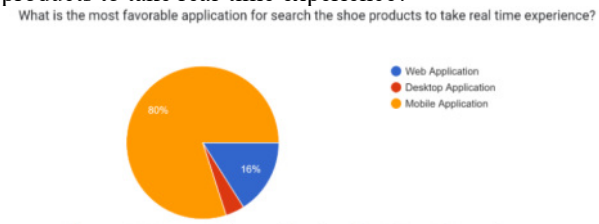

Figure 9. Favorable application for Shoe Shopping

Analysis and Interpretation: The chart shows the most favorable application for search shoe products. It's clear that people these days choose mobile applications for their everything because mobile phones are becoming the easiest way to access and keep searching for a long time.

V. ANALYSIS & SOLUTION

Now researcher understood all the aspects of the users. The researcher needs to verify which augmented reality technology is more applicable for implementing mobile applications since its users preferred the way. After analysing the research papers, and the websites based on AR technology as it was mentioned in the above literature review, the researcher found that there are three usable AR technologies available for the use case. AR platforms that are accurate and supportable for mobile development are the main considerations when searching for technology. Foot gesture detection is the major task of these applications. Founded three possible technologies that can be used with mobile development were, AR Core, AR Kit & DeepAR. Then to find the best matching technology for this scenario researcher has gone through a comparison of the features.

Table 1. Feature Comparison of AR Techniques

Features	ARKit	ARCore	DeepAR
Plane Detection (Vertical)	x	✓	✓
Plane Detection (Horizontal)	x	✓	✓
Feature Point Detection	x	✓	✓
Light Estimation	✓	✓	✓
Hit Testing (Feature point and plane ray casting)	x	✓	✓

Image Tracking	✓	✓	x
3D Object Tracking	x	✓	✓
Background Segmentation	✓	x	✓
Physics	x	✓	✓
Object Placement	x	✓	✓
Particles Support	✓	x	✓
Android Support	x	✓	✓
iOS Support	✓	x	✓
Web Support	x	x	✓

The above table 1 shows the results of the comparison done by the researcher. When comparing the features of these three techniques, the researcher identified that DeepAR has been able to supply all the features that matched the requirements of the proposed application. The key point that can notice is that DeepAR is supported by all major operating systems like Android & iOS. The sample population preferred mobile applications among others to buy shoes with. The major two parties of mobile users are Android users and iOS users, so this application might be very useful to reach both of these customer bases to get the maximum output from the product application.

Here researcher discusses how DeepAR is supportable for the functionalities of the proposed system. To consider the foot placement environment DeepAR gives the feature of horizontal & vertical plane detection. And background segmentation feature supports detaching the background from the identified object (foot). Recognizing foot gestures is the main function of visualizing the shoe in real-time. So, DeepAR gives more accurate feature point detection and 3D object tracking which helps to detect foot gestures and movements. After identifying the accurate foot gestures and movements DeepAR acts according to the feature points and using the object placement feature, is supposed to place the shoe model on the foot. Then customers will be able to check the fit and feel of wearing the shoe models as they preferred. And also, this proposed system will be able to estimate the light conditions of the environment and react according to that, with the help of the light estimation feature of DeepAR. Finally, the researcher is supposed to use DeepAR SDK for the proposed mobile application which allows a virtual try-on experience for the customers.

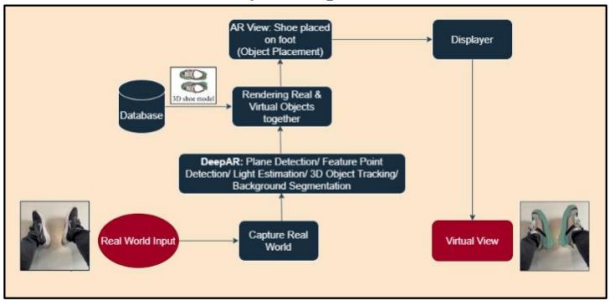

Figure 10. Shoe Try-On Process

VI. CONCLUSION & RECOMMENDATION

After all the clarifications researcher has done a great task to complete the main objectives of the research. The researcher analyzed the challenges faced by users during the current shoe shopping systems. Then analyzed the users' opinions to enhance the performance of the current footwear buying experience. After that researcher analyzed the performances of the augmented reality technologies which can be applied to enhance the effectiveness of the footwear selling systems. By examining all the data, the researcher came up to a conclusion on applying DeepAR technology for the proposed mobile application. It is more applicable in this situation to enhance the performance of the online shoe-selling market. The following diagram will illustrate a simple conceptual flow that elaborates on the concept of implementing the AR-based shoe try-on mobile application.

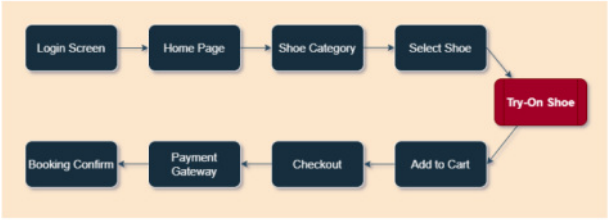

Figure 11. Conceptual Diagram of Proposed system

From the factors discussed, the researcher proved that the novel functionality of giving the option to try-on-shoe in real-time can increase the customer's interactivity and the intrusive value towards the product which is expected to buy. Hence, would be able to increase the businesses and the interaction towards online shoe shopping. This analysis proved that the hypothesis build by the researcher is valid and it shows that AR techniques can be used to solve the problems and enhance the effectiveness of the footwear industry based applications. The researcher has built this proposed system architecture by using proper research methodology and trustworthy information gathered through real users of footwear applications and credible resources. So, the researcher believes that the implementation of this proposed system would be highly successful. As further work researcher is recommending building and implementing this system for footwear-selling companies. And also, researcher is expecting to build this system as a continuation of this research.

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