EXPLORATION OF LASEM BATIK MOTIFS THROUGH A FITTING TOOL "ARBATULA" APPLICATION BASED ON AUGMENTED REALITY

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ABSTRACT

Lasem batik is one of the prestigious cultural products of Rembang Regency, with distinctive motifs including Sekar Jagad, Latohan, and Watu kricak. Lasem batik faces an existential crisis due to declining interest among the younger generation in preserving it. Various efforts have been made, one of which is by academics who have made Lasem batik a research topic by adapting digital technology as a representation of the lives of the younger generation. The most basic preservation of Lasem batik can begin with the introduction of motifs through fashion, in line with current trends. This became the basis for the author to conduct exploratory research on Lasem batik motifs through the Fitting Tool application based on Augmented Reality technology. Both have been applied in the fashion industry, but have never been applied to Lasem batik motifs. This research uses a Research and Development method that is oriented towards innovative product development and descriptive presentation. Data collection was conducted through observation, interviews, and documentation at the Lasem Batik Cooperative, supported by a literature review of journals and books on Lasem batik. The main result of this research is the "ARBatula" application prototype, which simulates an Augmented Reality-based fitting tool to display Lasem batik motifs on 3D fashion through markers with several features such as gender selection, motif selection, and mode selection. The results of this research are expected to attract the attention of the younger generation in an effort to preserve the existence of Lasem batik through a technological and fashion approach.

KEYWORDS

ARBatula, Augmented Reality, Batik, Fashion, Fitting Tool, Lasem, Motif.

INTRODUCTION

Lasem is an area on the north coast of Rembang Regency where Cheng Ho stopped in 1413 [1], to the point of being called "Little China or Little China" [2][3]. Its strategic geographical position made Lasem a stopping point for visiting ships in the past, which had an impact on the development of batik with its distinctive color composition, motifs, and decorative patterns [4][5]. Lasem batik is known as one of Indonesia's cultural heritages resulting from the acculturation of Javanese, Chinese, Arabic, Indian, and European cultures [6]. China, in particular, has a strong influence on the textile industry in Southeast Asia, especially batik [7]. Lasem batik is not just a textile, but a cultural artifact rich in heritage and identity with high historical, aesthetic, and symbolic value [8]. This was reinforced by UNESCO's designation of batik as a Masterpiece of the Oral and Intangible Heritage of Humanity on October 2, 2009 [9][10][11][12]. Lasem batik is not only a cultural icon, but also a leading commodity [13], which originated from home-based industries, along with other regions such as Solo, Cirebon, Pekalongan, Semarang, Yogyakarta, Pati, Surabaya, and Madura [14][15][16]. To this day, batik making remains the livelihood of Lasem's residents [17][18].

Despite its popularity as a cultural icon, the current condition of Lasem batik is worrying. The Lasem batik industry is experiencing a decline amid the rise of Western fashion trends due to globalization [19], as well as urbanization [20]. The heyday of Lasem batik occurred in 1970 [21], with 144 industries [22], decreased to 120 industries in 2017 [23], and become 78 industries in early 2024 [24]. Public appreciation has also declined, making it difficult to regenerate the younger generation, who prefer to work in modern sectors, both inside and outside Rembang [25]. The problem of transferring batik skills from experienced craftsmen to the younger generation has yet to be solved and continues to this day [26]. The Lasem batik production process takes a long time, while the younger generation prefers instant gratification [27].

Based on the author's observations and interviews on May 31, 2025, at one of the Lasem batik artisan groups, only women aged 50 and above still have the

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motivation to continue batik making. The existence of Lasem batik, which maintains the writing technique to preserve its quality and authenticity [28], also faces the threat of imported batik, which offers lower prices [29]. The decreasing number of batik artisans has resulted in minimal exploration and innovation in existing batik motifs. Motif variations are limited and tend to be repetitive and stagnant, highlighting the need for more innovation in creating new motifs [30]. If old motifs continue to be used without change and the spirit of batik making is not passed on to the younger generation, it will be difficult to regenerate batik artisans and the cultural heritage of Lasem batik could become endangered in the future [31].

The various issues above are interrelated and point to one main issue, namely the challenge of preserving Lasem batik. Preservation and inheritance must be carried out to maintain the values, norms, and cultural products of batik for the younger generation by adapting to the current environment [32], Amidst the rapid globalization and development of digital technology, Lasem batik artisans and business owners are predominantly middle-aged, or what is known as "Generation X." The conventional learning process in the past was oriented towards books, pictures, and writing [33], This is one of the factors limiting this generation's knowledge and skills in utilizing digital technology. Meanwhile, the younger generation, consisting of millennials (Generation Y) and Generation Z, were born and raised in an era of rapid growth in digital media, making them adaptable to technologies based on artificial intelligence, the internet, virtual reality, and wireless technology [34].

Generation X is the group born between 1961 and 1980, millennials were born between 1981 and 1995, and Generation Z were born between 1996 and 2010 [35]. Based on 2020 census data, Indonesia's population composition is dominated by Generation Z and Millennials in first and second place, with 74.49 million and 69.9 million people, respectively [36]. Collaboration between Lasem batik artisans or business owners from Generation X and Millennials and Generation Z can create strong and diverse synergies, with the potential to generate rapid business growth, rich innovation, broader marketing, and sustainability [37].

Digitalization and rapid technological developments have also driven the expansion of batik into a fashion trend related to current clothing styles, as a form of self-expression and representation of national identity [38]. The younger generation (especially Generation Z) is highly curious and inquisitive, and readily follows varied and dynamic fashion trends [39]. Since long ago, batik has also been developed into a fashion product because of its economic value. This is an opportunity to introduce and pass on Lasem batik, which can begin with the exploration and development of old or new motif designs as an attraction for the younger generation [40]. The introduction and exploration of Lasem batik motifs are very important, because the younger generation in Rembang Regency, especially in Lasem, are not yet fully aware of its uniqueness as a heritage with high artistic value [41]. The fashion approach is one method that can be applied in line with the characteristics of the younger generation.

On the other hand, digital technologies such as Augmented Reality, Virtual Reality, Artificial Intelligence, Interactive 3D, Metaverse, and the like, are beginning to be adapted in various fields, including fashion, giving rise to the term digital fashion [42]. Some of these include: Augmented Reality-based virtual fitting to enhance the sneaker shopping experience [43][44], App-based virtual fitting for fashion e-commerce that utilizes data such as weight and height for body measurements [45], NFT-based virtual fashion through websites as a form of digital innovation to reduce clothing waste [46], Augmented Reality-based fashion design interface using deep generative models to visualize clothing designs in real time based on input images [47], Digital fashion based on virtual technology through the principles of holographic photography imaging as a new way to interact with consumers [48], Augmented Reality-based Smart Fitting application for virtual clothing model trials that displays various categories, colors, and sizes [49], as well as clothing designs using a Generative AI approach that offers customization and user engagement for real-time styling [50].

The various examples of digitization above are still general in nature and none of them have used Lasem batik as the subject of experimentation, making them potential subjects for research. Given the urgency of preserving Lasem batik for the younger generation amid the inevitable application of digital technology, and as a first step, the researcher conducted research focusing on the development of "ARBatula" as a prototype application fitting tool to explore Lasem batik motifs based on Augmented Reality technology. "ARBatula" is the name of the application, which is an acronym for "Augmented Reality Batik tulis Lasem" (Lasem Handmade Batik Augmented Reality). It is only fitting that Lasem batik artisans, potential heirs, and other related parties embrace various digital technologies as a new way of interacting with fashion cultural heritage [51].

This is relevant to efforts to digitize cultural heritage from the local to the global level, which take advantage of trends in technology and media

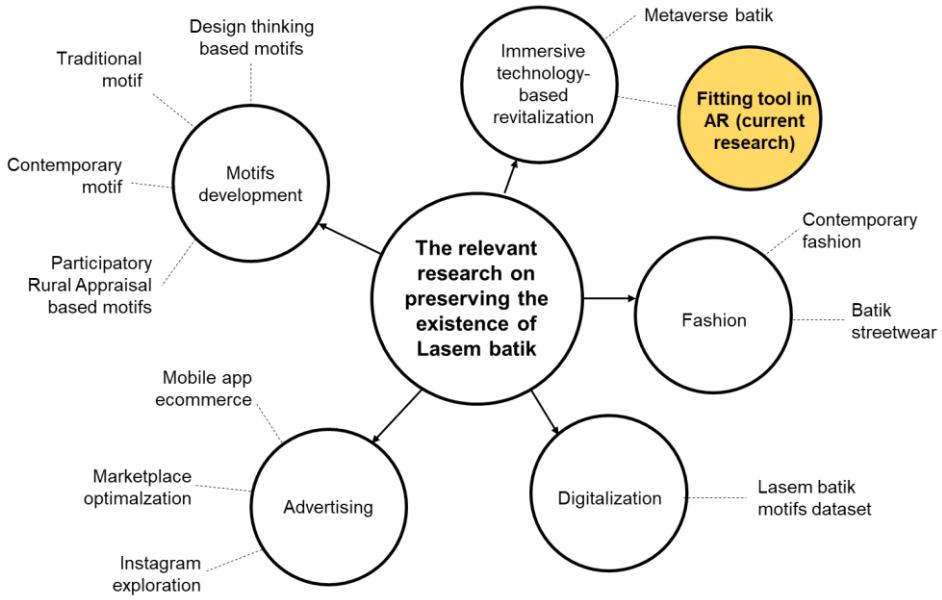

Figure 1. Mapping of research relevant to the topic of Lasem Batik.

development. The preservation of digital-based cultural heritage has become a focus for researchers in order to improve accessibility, create institutional collaboration, and improve restoration and conservation efforts to ensure that cultural and digital integration is maintained [52]. Preservation can be achieved through Digital Twin Technology, which transforms public access to cultural heritage through virtual tourism, Augmented Reality, or immersive digital museums to create interactive cultural heritage experiences and ensure that cultural heritage remains intact for future generations [53]. Augmented Reality, Virtual Reality, and 3D Modeling are the most widely used types of technology for preserving cultural heritage [54].

Some examples include the Olympia archaeological site and the old town of Chania in Greece, which use outdoor augmented reality to bring to life archaeology, artifacts, and ancient monuments that have been destroyed, such as the glass mosque; or Qasr al-Abd Palace in Jordan, which offers smartphone-based augmented reality as a guide for visitors [55]. The preservation of cultural heritage in Indonesia also utilizes similar technologies, some of which include: preserving the traditions of the archipelago (landmarks, traditional foods, dances, and traditional clothing) through interactive cultural experiences packaged in smartphone applications [56], displaying virtual 3D objects of sculptures or statues from East Kalimantan [57], introducing artifacts from the North Sulawesi Provincial Museum in virtual 3D form [58], and reconstructing the story of Borobudur reliefs through a digital book application [59]. The above studies show that the synergy between cultural heritage preservation and digital technology, especially Augmented Reality-based technology, is the right choice from various aspects.

RELEVANT RESEARCH AND NOVELTY

Relevant research on Lasem batik

The critical condition of Lasem batik has become a concern for several parties, ranging from the government, academics, practitioners, to investors [29][60]. Academics, in particular, have conducted various studies in an effort to preserve Lasem batik. Research related to motif development includes: exploration of batik motifs depicting bouquets of kawis fruit [61], designing contemporary batik motifs based on the cultural aesthetics of Lasem batik motifs [62], study on the development of Lasem Rembang hand-drawn batik motif designs [63], interpretation and implementation of Latohan motifs in Lasem batik [64], designing new motifs through Participatory Rural Appraisal (PRA) [31], and exploration of Lasem batik motifs through Design Thinking [30]. Research related to promotion and advertising efforts, including: UI-UX design for Lasem batik e-commerce based on mobile applications [25], Utilizing e-commerce to increase sales of Lasem hand-drawn batik MSMEs [65], as well as the use of Instagram social media as a means of promoting Lasem batik fashion [13]. Research that highlights Lasem batik as fashion includes: the application of Lasem batik in contemporary clothing designs [66], as well as ideas for designing women's streetwear based on acculturation in Lasem batik [67]. Lasem batik became the subject of research from the perspective of digital and virtual technology, namely: the adaptation of the metaverse as a form of readiness for Lasem batik MSMEs [68]. Recently, Lasem batik has also been the subject of research in the development of a compilation dataset of batik fabric product photos, as a visual reference and mapping of Lasem batik based on motif images [69]. These relevant studies can be grouped into five major

themes, namely: motif development, advertising, batik fashion, digitization, and revitalization based on immersive technology.

The various relevant studies above have one thing in common, namely adapting digital technology and platforms. In addition, the above description shows that the development of a fitting tool application to explore Lasem batik based on Augmented Reality has never been done by other researchers. This is a novelty or state of the art of research that raises Lasem batik as a topic and object of research. Figure 1 shows a mapping of relevant studies discussing Lasem batik, while also showing the position of this study, which falls into the category of revitalization based on immersive technology. The adaptation of Augmented Reality technology has the potential to explore batik motifs in line with fashion trends that are relevant to the younger generation.

Relevant research on augmented reality batik and similar fashion products

Augmented reality is a variation of a virtual environment in the form of computer-generated digital information, whether it be images, audio, video, or even touch or haptic sensations, overlaying it in the environment in real time [70]. Its use in batik products and various fashion items has been explored by previous researchers. Its implementation has led to the Virtual Try-On system, which is a fashion textile modeling system or technique that allows potential buyers to try on or change various virtual clothes that are attached to a real human body using computer vision techniques, and displayed on a monitor or other device screen. The Virtual Try-On system has several advantages for both potential consumers and fashion producers, including [71]. Creating an inclusive experience in trying on virtual clothing comfortably and conveniently at home, encouraging potential customers to quickly and accurately assess and decide on the suitability of the product they want to buy, and reducing the potential for order cancellations due to incorrect sizes or clothing model choices. Virtual Try-On in the fashion world has become a major focus and has been proven to have significant benefits in overcoming production redundancy issues to reduce clothing waste [72].

The application of Virtual Try-On in the form of Augmented Reality on batik products (slow fashion) has been carried out by two groups of researchers from Indonesia in 2022 and 2025. The first was the initial development of a Virtual Try-On platform for batik fashion based on Mobile Augmented Intelligence Technology, which utilizes three hand gestures: a point gesture to point and activate batik motifs, a grab gesture to select and pull motifs, and a release gesture to remove motifs on 3D fashion models [73]. The result is a prototype application for mapping batik motifs onto 3D fashion models attached to virtual mannequins, rather than onto the user's body in real time. The second is Augmented Reality for Virtual Try-On of East Kalimantan batik through the Tiktok application [74]. The result is a virtual mapping of Lai batik motifs onto a 3D fashion model on the user's body, which can display front, side, and back views according to the orientation of the user's body position. In addition, the visualization and shape of the fashion model are differentiated based on gender.

The use of Virtual Try-On has also expanded to other fashion products, such as glasses, watches, sneakers, and casual clothing (fast fashion). Researchers from Nepal have developed an Augmented Reality-based Virtual Try-On system for glasses on a web platform that utilizes a webcam to display virtual glasses based on the shape and size of the user's face [75]. The principle of operation is to capture the face and follow the position of the user's face (head straight or tilted), similar to how AI cameras work, which are now a default feature on smartphones. Major companies such as Prada and Warby Parker have long been using this technology to promote their eyewear products. Researchers from Stanford University have developed "GlamTry," a virtual try-on for watches, using watch photo data that is extracted and turned into a virtual object that can appear on the user's arm through body detection [76]. As implemented by Rolex and Baume & Mercier to promote their luxury watches, researchers at Hanyang University have developed "ARShoe," a virtual try-on product for sneakers that can display products based on photos of the user's feet [44]. This has also been done by researchers from Beihang University, who have developed Virtual Fitting for sneakers on online shopping applications [43]. Both have similarities in displaying 3D sneaker objects based on the position and direction of the feet and the length of the feet based on camera capture results. A large company that has utilized this technology is Nike.

Virtual Try-On paling banyak diadaptasi untuk produk baju kasual, baik yang bersifat eksperimental maupun implementatif. Peneliti dari Mesir mengembangkan “FITMI”, Virtual Try-On berbasis web untuk merevolusi belanja online secara realistik [77]. Website menyediakan menu untuk mengunggah foto fashion atau memotret langsung dari kamera sebagai input data visual, hal ini juga berlaku untuk foto pose pengguna. Hasilnya yaitu tampilan produk fashion pada foto pengguna yang diunggah sebelumnya. Peneliti dari Saudi Arabia mengembangkan “Smart Fitting”, Virtual Try-On berbasis smartphone yang bisa menampilkan produk fashion beragam bentuk, model dan warna berdasarkan data pindai tubuh pengguna melalui kamera [49]. Metode yang diterapkan dalam “Smart Fitting” yakni overlay virtual fashion model juga diterapkan pada hampir semua Virtual Try-On sejenis yang telah dilakukan peneliti lainnya. Hal ini tidak terlepas dari sifat real-timedan kemudahan akses.

Perusahaan yang telah menerapkan ini dalam produk fashionnya diantaranya: H&M, Zalando, dan Levi Strauss & Co.

Berbagai penelitian relevan di atas menunjukkan bahwa Virtual Try-On menjadi sarana eksplorasi sekaligus promosi beragam produk fashion yang telah mendunia. Meskipun sudah diterapkan untuk fashion batik, namun belum ditemukan penelitian Virtual Try-On produk batik Lasem. Hal ini menjadi temuan baru yang berpotensi dikembangkan sebagai upaya melestarikan batik Lasem melalui eksplorasi motifnya, yang secara tidak langsung juga memperkenalkan dan mempromosikannya dengan pendekatan digital.

RESEARCH METHOD

This study uses a Research and Development (R&D) approach with a structured development model oriented towards innovative product development and descriptive presentation. Descriptive research is research conducted to ensure and enable researchers to describe the characteristics of issues of concern in real conditions and situations. In this context, researchers understand the issues or phenomena surrounding Lasem batik based on facts and field conditions. The purpose of descriptive research is to obtain a complete profile or description of relevant aspects of an interesting phenomenon that occurs in an individual, organization, industry, or other matters.

Data collection was conducted through observation of Lasem Batik MSMEs, interviews with MSME managers, and literature studies on relevant research that highlighted Lasem batik as the object of study. Data from these various methods was taken into consideration in the development of the fitting tool application. The research was conducted in several systematic stages that combined cultural studies, visual exploration, digital technology development, and evaluation. The main objective of this method was to produce a prototype of an interactive fitting tool application that was not only functional, but also had cultural and educational value.

The initial stage began with a preliminary study through observation, interviews, literature studies, and documentation of Lasem batik, including: motifs, dyeing techniques, cultural values, and current challenges. The exploration and documentation of Lasem batik motifs was carried out by taking motif samples, photographing them, and converting them into digital assets for design purposes. The results of the information gathering are taken into consideration for needs analysis, namely identifying the needs, challenges, and opportunities for developing a fitting tool as an effort to explore batik motifs based on Augmented Reality. Device requirements and target audiences need to be presented to ensure relevance to the research focus.

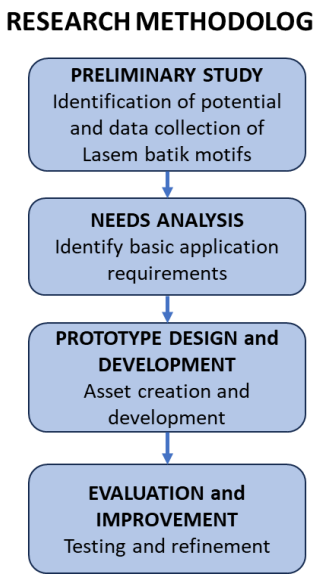

Figure 2. Research method steps.

After determining the requirements analysis and target audience, a flowchart of the fitting tool application prototype was mapped out and the user interface was designed. The prototype was developed using interactive application technology (Blender, Unity, or similar programs), with the integration of batik motif libraries. At this stage, users can select motif designs and see a real-time visualization of the motifs on products such as clothing. After development was complete, an evaluation (testing) of the interface and navigation flow was conducted, which served as the basis for improvements and refinements to the application prototype.

RESULTS AND DISCUSSION

Identification of potential and collection of data on Lasem batik motifs

Lasem batik still has enormous potential to be introduced more widely, especially to the younger generation. The author's observations of one of the Lasem batik cooperatives in May and June 2025 resulted in the documentation of ten motifs, which were selected based on the preferences of batik craftsmen. The documented motifs are four types that are quite popular, namely: Sekar Jagad, Truntum, Gringsing, and Lereng. These motifs are local motifs unique to Lasem that were developed independently by the cooperative, not well-known acculturated motifs such as Burung Hong and Naga. This aims to promote local motifs so that there is no imbalance with acculturated motifs. In addition, it also provides an opportunity for Lasem batik artisans to develop new motifs in an effort to enrich the repertoire of Lasem batik motifs.

Figure 3. Observation of the batik-making process and documentation of ten Lasem batik motifs.

Figure 4. Interview with the head of the Lasem batik cooperative regarding efforts to introduce motifs.

Figure 3 shows the author's observation of artisans making batik motifs on a piece of cloth. Artisans are challenged to create motifs that are different from those they have made before. This is aimed at creating novelty. Artisans may make old motifs, but they must be accompanied by new motifs to produce a variety of motif combinations. The more complex the motif, the more expensive the price. The ten batik motifs above are examples of motifs with two to three images and three color combinations. The fabrics produced by the Lasem batik cooperative consist of three types based on color, namely: two colors, three colors, and more than three colors. Batik with two colors has the lowest price, three colors has a medium price, while more than three colors has the highest price.

The author interviewed Mrs. Sri Wahyuni, chairperson of the Lasem batik cooperative, and learned that batik artisans are on average over 50 years old and still maintain traditional methods in motif creation, sales, and presentation or exhibition of Lasem batik. Catalogs are used to display motif collections, including photos, names, and prices. Artisans do not yet have the knowledge or experience to use digital media or technology in the batik industry. The catalog they have is also the output of the 2016 Work Study Program, which has not been updated to date. This medium is not relevant to the younger generation, who are more familiar with digital media than conventional media. The Lasem batik cooperative must see the opportunities and potential that exist, namely introducing and showcasing the Lasem batik collection through its motifs by utilizing digital technology that is adapted and used in the world of fashion, namely an Augmented Reality-based fitting tool.

Needs analysis

Relevant research shows that there has been no introduction of Lasem batik motifs through Augmented Reality-based fitting tools. On the other hand, the potential and use of Virtual Try-On as an implementation of Augmented Reality is important in various fashion products. As stated by the author at the end of Introduction, one relevant way to preserve Lasem batik for the younger generation is through pattern recognition. This is a major consideration in the development of a fitting tool in the form of Virtual Try-On to explore Lasem batik patterns in 3D fashion models that can be accessed in real-time based on the working principles of Augmented Reality. Of the ten batik motifs observed and documented by the author, there are four Sekar Jagad motifs used for the application content. Sekar Jagad is a motif that is

often made by craftsmen, as well as one of the famous and original motifs typical of Lasem. This motif has a main visual in the form of a flower interspersed with kricak (small stone fragments), latoh (seaweed), vines, or tumpal.

The selection of Virtual Try-On as an Augmented Reality-based fitting tool development is relevant to the needs and behavior of consumers from the millennial and Generation Z groups as digital native generations. Consumer behavior is the study of individuals, groups, or organizations related to the consumption of products or services based on important decisions ranging from choosing, buying, using, to evaluating them in order to fulfill needs or desires [78]. The use of Virtual Try-On for consumers has the potential to increase the entertainment value of the online shopping experience and enhance the overall consumer experience [79]. On a broader scale, namely digital marketing campaigns, Augmented Reality integrated with social media applications (such as TikTok) can increase consumer engagement and trust, strengthen brand preference and loyalty, and encourage purchase intent [80][81][82].

The potential and benefits of Virtual Try-On are not only enjoyed by people in Western countries (Europe and America), but also in Eastern countries (Asia). The existence of Virtual Try-On for consumers in India, Bangladesh, and Indonesia provides the same benefits, namely influencing purchasing decisions, creating unforgettable experiences, increasing consumer loyalty to brands, which ultimately helps countries to grow collectively in terms of technology [83][84][85][86]. This means that the use of Virtual Try-On is not only beneficial on a small scale for fashion manufacturers and consumers, but on a larger scale it also demonstrates a country's progress and readiness to adapt to technology.

Prototype design and development

The fitting tool application to be developed is a Virtual Try-On prototype based on Augmented Reality that can be accessed using an Android smartphone. Batik craftsmen are not accustomed to using technology or digital products, so an easily accessible application is needed to avoid difficulties. The application works by adapting the marker-based Augmented Reality model popularized by Siltanen [87][88].

The fitting tool was designed through six stages. First, four of the 10 motifs photographed during observation were selected. The four motifs were Sekar Jagad with different color variations and motif images. The first motif depicted yellow flowers and peacocks with a black background. The second motif depicted white flowers with a red background. The third motif depicted red and white flowers with a black background. The fourth motif depicts bright pink and white flowers with a dark blue background.

The second stage involves digitally mapping the visual data of the motifs using Adobe Photoshop graphics processing software. This software has features and functions for simple 3D object processing. This is also known as texture mapping or warp texturing. Each visual motif data is analyzed based on a specific pattern, cut, and arranged in such a way that it is suitable for texturing on a 3D fashion model. The mapping and texturing results are saved in png format. The challenge in this stage is placing the main flower motif as the foreground on the 3D fashion model.

The third stage is the creation of a 3D fashion template that will be used as an area for digitally mapping batik motifs to visualize virtual fashion shirts. The author chose Blender, a specialized 3D object software, to accommodate this need. The 3D fashion model was created with medium polygons to keep the file size small while maintaining a smooth shape. The 3D fashion object was saved in gITF/GLB format so that it could be accessed for designing an Augmented Reality-based application.

The fourth stage is the design of the user interface and graphics needed in the application. The user interface includes navigation buttons, while the graphics consist of the application's start screen and the User Manual display. These assets were designed using Adobe Illustrator and Photoshop software and saved in png format in accordance with the characteristics of the application's requirements.

The fifth stage is the development of the application using Unity3D multimedia software. The program code is written to synchronize the user interface, texture mapping, and 3D virtual fashion so that it can display a virtual shirt that maps the Lasem batik motif. The final compilation of the application is in .apk format so that it can be installed and accessed using a smartphone.

The sixth stage is the creation of a QR code using AR Code, as a marker to bring up a virtual 3D shirt. Marker-based augmented reality has the technical advantage of being simpler and easier to implement because it only displays virtual objects based on QR codes to avoid the potential distraction of unnecessary objects. Meanwhile, the markerless model does not require a QR code, but it must be supported by sensor features such as GPS and inertia to determine the position and orientation of objects, which results in higher smartphone specifications. In addition, the markerless model is also prone to unnecessary visual distractions that can interfere with the main object.

The application, which has been compiled and installed on a smartphone, is ready to use, but all 3D asset data, textures, and information are accessed offline. For more details, the application design, starting from the name, form, function, and tools used for its development, is presented in Table 1.

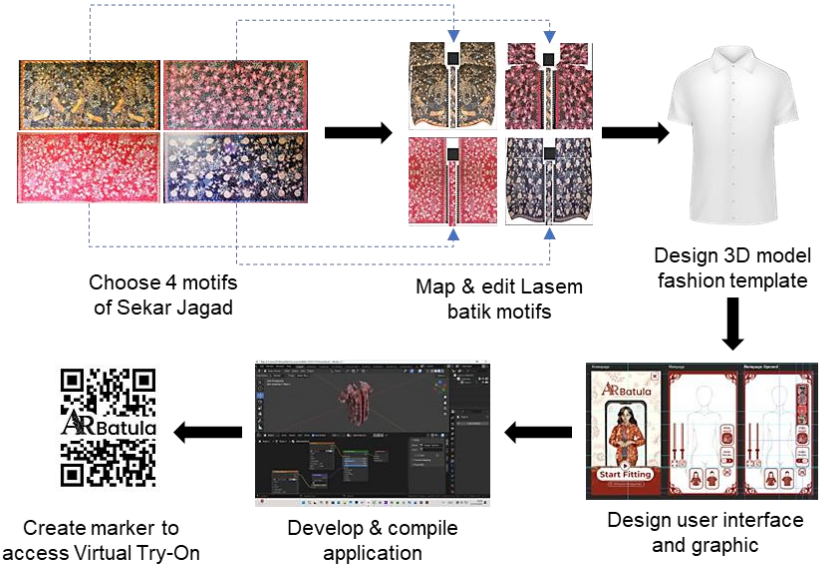

Figure 5. Application design and development process.

Table 1. Application design details and tool requirements.

Criteria	Specifications / Scope	Description
Developed products	"ARBatula"	"ARBatula" is an acronym for "Augmented Reality Batik tulis Lasem" (Lasem Handmade Batik Augmented Reality). This name was chosen for its ease of pronunciation, and has never been used for any other digital product.
Product form	Fitting tool application in the form of Virtual Try-On based on Augmented Reality	The implementation of Virtual Try-On as an Augmented Reality-based fitting tool application has been widely used, based on relevant research presented previously.
Functional requirements	Pattern recognition and mapping in 3D fashion	Introducing Lasem batik motifs with a digital approach through fashion visualization that is relevant to millennials and Generation Z.
Development device	Notebook	• Prosesor Core i5-10210U • 8GB RAM • Operating system Windows 10 • SSD M2 PCIe 512 GB • GPU Intel Graphic HD & NVIDIA GeForce MX230 2GB • Display 14" FHD (1920x1080)
Development software	Virtual Try-On design	• IDE: Unity 3D LTS 2020.3.x • Compiler: Xcode 13 • AR Library: ARFoundation 4.1 & ARKit 4
Test device platform	Smartphone	• Device: Samsung Galaxy A25 5G • Chipset: Exynos 1280 (5 nm) • OS: Android 14 • CPU: Octa-core (2x2.4 GHz Cortex-A78 & 6x2.0 GHz Cortex-A55) • GPU: Mali-G68 • Main camera: 50 MP, f/1.8, 27mm (wide), 1/2.76", 0.64µm, PDAF, OIS • Sensor: Gyroscope

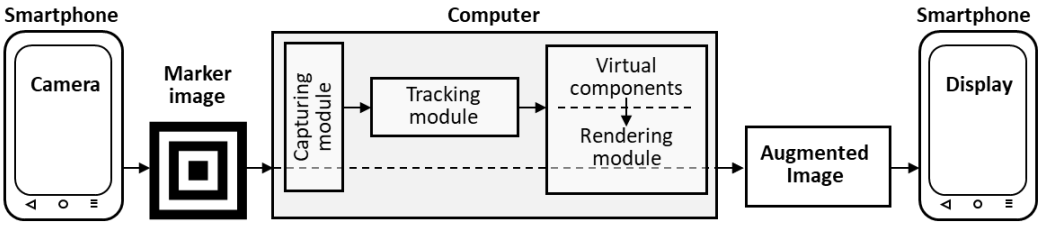

Figure 6. Marker-based Augmented Reality model on "ARBatula".

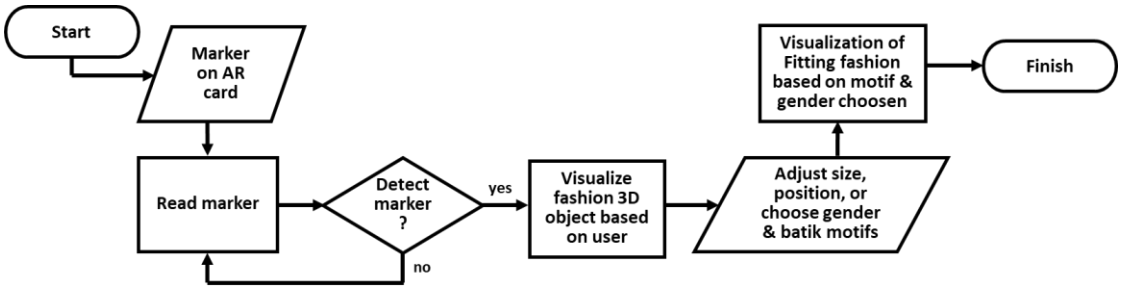

Figure 7. The "ARBatula" workflow.

Figure 8. The initial display of "ARBatula" and the tutorial User Guide.

Figure 9. The process of fitting scan markers on male (left) and female (right) models.

Figure 10. Final appearance of the fitting on men (left) and women (right).

Table 2. Recommendation Matrix for Improvement of the fitting tool application "ARBatula".

No	Problems Found	Impact	Recommendation for Improvement	Priority
1	The camera is a little slow to activate when starting the fitting	Lower user experience, users have to wait	Optimize camera initialization, perform camera module pre-loading	High
2	Objects were slightly blurred in some experiments	Reduced fitting quality, less clear display	Add an auto-focus feature or a notification when an object is not in focus	High
3	Batik motifs appear with a pause (slow loading)	Users feel the application is less responsive when changing motifs	Apply caching or preloading for 10 batik motifs	Medium
4	Adjustment of shirt size lacks precision	Unrealistic fitting results, the size looks unnatural	Improve the scaling algorithm, add more detailed step sliders	High
5	Male/female models are sometimes slow to change	Slightly disrupts the flow of use, but is still usable	Optimize model rendering with image compression or preload	Medium
6	Storage of fitting results is limited to the default format	Users do not have the option of file quality/format as needed	Add format options (PNG/JPEG) and storage resolution	Low

The Virtual Try-On prototype works as shown in Figures 6 and 7. The process begins with input from a smartphone camera pointed at a marker image in the form of a card. The marker contains digital data in the form of a 3D virtual shirt object. When the marker is scanned, the application prototype is computerized from the module. The module is part of the Augmented Reality application with specific functions. The capturing module functions to take, capture, and read digital data of Lasem batik motifs presented in the form of a QR code. The tracking module functions to detect and track markers to determine the position of virtual objects. If the marker is not detected, the process returns to read marker (capturing & tracking module). If the marker is detected, it proceeds to the Rendering module stage. This stage combines the results of the capturing and tracking processes to produce an augmented image that combines the real world with virtual elements, namely a 3D visualization of a Lasem batik-patterned shirt. When the fitting object appears on the screen, users can change the size and position of the object as needed, as well as select the gender and motif variants available. The display results can be viewed on the smartphone screen in camera mode, in the form of a fashion fitting visualization based on the selected pattern and gender. The results can be saved to the smartphone gallery in jpg image format.The "ARBatula" fitting tool application is designed and packaged as simply as possible for easy user access. On the initial screen, there are two menus: "Start Fitting" and "Instructions for Use." Users can simply press the "X" button on the top right of the screen or press the "Back" button on their smartphone to exit the application. If users are accessing the application for the first time, it is highly recommended that they follow the Instructions for Use, which contains four step-by-step tutorial images. The first step is to prepare the QR code by hanging it on a lanyard to display the 3D fashion model on the model. After that, press "Start Fitting" to enter the main camera on mode display. Once in active camera mode, point and adjust the model's body so that the upper half of the body is within the camera frame. Finally, the application is ready to use with buttons that can be accessed as needed. Illustrations of each step can be accessed by swiping the screen to the right or left as desired.

Testing the "ARBatula" Fitting Tool

The "ARBatula" application can be used to display male and female fitting tool models. As explained in the tutorial above, the application can run when the user attaches a marker using a lanyard. The smartphone is pointed at the model and the distance is adjusted so that the body parts appear in a medium shot, as shown in Figure 9. When the marker is read by the camera, the dark red Sekar Jagad patterned 3D fashion model automatically appears as the default, followed by a menu navigation that users can access, including: pattern selection, pattern mapping mode selection, gender, and saving the fitting results.

Users can change the Lasem batik motif using the "Select Motif" button on the right side. There are four Sekar Jagad motifs that can be selected to change the appearance, including the default motif. To change the batik mapping mode, users can access it via the "Select Mode" button. At the bottom, there is a Select Gender button to change the mode from male to female or vice versa. The application is designed so that when the user is male, a shirt model appears. Conversely, if the user is female, a blazer model appears. Finally, there is a Camera button at the bottom right to capture the screen image or save the fitting results to the gallery. The fitting results not only provide a simulation of the fashion design for users when making clothes from Lasem batik fabric,

but also serve as a reference for tailors regarding the planning of clothing patterns that match the desired motif shape to highlight the characteristics of the motif.

Evaluation and Improvement

Evaluation of the "ARBatula" Prototype was carried out using the User Acceptance Test (UAT), which is the last testing stage in the software development cycle. In this UAT, end-users or clients test the application to ensure that the application: matches the business needs that have been defined at the beginning (requirements), functions properly in an environment that is close to real conditions, and is ready to use. UAT was conducted involving 5 client representatives and 10 end-users. The test scenarios covered the main features of the application, including: image capture, gender selection (Male/Female), batik motif, fashion mode, size adjustment (slider), and saving fitting results. From the UAT results, most of the evaluations showed results that were in line with expectations. There are some minor findings, such as a camera that is a little slow to activate, batik motifs that are somewhat late to display, or fitting sizes that are less precise in some experiments, but still get the status of "Pass with notes" because it does not hamper the main function of the application. In general, the UAT results from all users stated that the application can be used properly according to the initial needs.

Based on feedback from UAT participants, the application was accepted, with a few minor improvement recommendations as summarized in Table 2. The main recommendations given were to improve the responsiveness of the camera when starting the fitting, speed up the loading time of batik motifs, and add a finer size adjustment feature to make the fitting results look more realistic. Despite these minor notes, the application as a whole is considered feasible to use and ready to enter the wider implementation stage.

Table 3. Virtual Try-On Benchmarking: ARBatula, Batik Kalimantan Timur, Smart Fitting, and Zalando

Comparisons	ARBatula	East Kalimantan Batik	Smart Fitting	Zalando	Conclusion
Fashion items	Lasem hand-drawn batik	Lai Batik	Casual	Casual	ARBatula highlights batik as a unique local cultural product of Lasem, which has never been researched before in terms of virtual try-on.
Accessories	Smartphone	Smartphone	Smartphone	Smartphone	The four virtual try-ons are accessible via smartphone.
How Augmented Reality works	Scan marker	Scan marker	Markerless	Markerless	ARBatula chose to use markers to reduce visual distractions, without worrying about the appearance of unnecessary virtual objects.
Menu in the application	Star Fitting, Instructions for Use, and Exit (three pages)	Scan Marker in the Tiktok app (multi-page)	Login/Register, Try On Cloth, Send Reviews, View Ratings, View Feedbacks (multi page)	Search/Choose fashion product, Choose Size, Create Own Board, etc (multi page)	ARBatula presents a concise menu of only three pages to make it easier for users and directly leads to the fitting tool without being affiliated with a specific application (stand-alone).
Virtual fashion display models	Attaches to the user's body	Attach to the user's body	Sticks to the user's body	Attach to avatar	Zalando has a different way of displaying virtual fashion, namely through user avatars. This actually has the potential to reduce accuracy.
Variety of virtual fashion items and their advantages	Two clothing models: men's and women's. Options to select gender, batik motif, batik pattern, change size using a slider, and save fitting results	Two clothing models: men's and women's, with one motif. Can display virtual fashion from the front, side, and back	Various models of casual women's clothing. Can choose various colors in virtual fashion	Various men's and women's fashion models. Multiview: can rotate virtual fashion 3600	ARBatula presents variations of men's and women's fashion based on user detection and offers a fairly complex display option that remains easily accessible within a single app view without having to switch screens, namely by selecting four different motifs with two mode variations. This is a unique feature offered and aligns with its purpose for exploring batik motifs.

Benchmarking between "ARBatula" and similar Virtual Try-Ons

The ARBatula application has been designed as an effort to introduce Lasem batik motifs digitally to the younger generation, packaged in a Fitting Tool in the form of a Virtual Try-On based on Augmented Reality. As explained in second chapter, Virtual Try-On is a technology that has been widely adapted for modern fashion products, and has only been applied three times to batik fashion, including the one done by the author. To provide a comprehensive overview, the author compares four Virtual Try-On products, namely: ARBatula, East Kalimantan batik Virtual Try-On (the result of batik clothing research), "Smart Fitting" (the result of casual clothing research), and Zalando (Zalando's professional Virtual Try-On). This comparison was conducted to highlight the differences, advantages, and disadvantages of each Virtual Try-On.

Potential for Sustainability and Cultural Relevance

The design and development of the ARBatula application is the first step in digitizing Lasem batik motifs using a Virtual Try-On approach based on Augmented Reality. Although its current importance lies in its role as an effort to preserve local culture, this application can still be developed further in the future, particularly in the commercialization of products and the ethical consumption of Lasem batik as slow fashion on a wider scale. The results of this research are currently limited to batik artisans, potential consumers within the scope of the batik cooperative, and academics. In the future, it is hoped that there will be further research on the development of the ARBatula application that can be integrated with the marketing or sales system owned by the Lasem Batik Cooperative. This has been done by professional fashion brands, so it may be beneficial to many parties, including batik craftsmen, the government, academics, design or multimedia practitioners, business partners, tailors, fashion designers, and the community or potential consumers. As a result, artisans affiliated with the Lasem batik cooperative can sell both fabric sheets and ready-to-wear garments digitally through Virtual Try-On, and can develop derivatives of Lasem batik fabric, such as scarves, headscarves, wallets, bags, and even shoes.

CONCLUSION

The implementation of the "ARBatula" application prototype as an effort to preserve Lasem batik through the exploration of motifs in the form of Augmented Reality-based fitting tools has been successfully carried out. Although there are shortcomings in the way the application works that need some adjustments based on testing, the output of this research is accepted and in accordance with the problems and objectives set at the beginning of the research. Fashion is the right approach and is suitable for the target audience, namely the Gen Z and millennial groups. Based on the recommendation table above, another main point to note is that the presentation of 3D fashion models tends to be formal and needs to adjust to fashion trends that are relevant to the Gen Z and millennial groups. This prototype can be developed better so that it really becomes a real solution that has an impact on the preservation of Lasem batik, and is expected to have an economic impact on Lasem batik entrepreneurs or craftsmen. Further development of the results of this research can combine the online shopping feature with the fitting tool feature, so that it can be widely applied.

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