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Advancing Electric Engineering Education through Immersive Virtual Reality: Deep Learning and Evolutionary Algorithms for Image Stitching and Rectification in Virtual Lab Environments

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Abstract. Virtual Reality (VR) technology has emerged as a transformative tool in education, offering immersive and interactive experiences that enhance learning outcomes. This paper delves into the application of image stitching and rectification techniques to create a VR lab environment, specifically tailored for electrical engineering education. The importance of VR technology in education is explored, highlighting its role in promoting active learning and providing experiential learning opportunities. The primary emphasis of this Paper lies in the smooth incorporation of image stitching algorithms for the creation of panoramic perspectives, along with the implementation of rectification techniques to correct irregular borders within the stitched images. By utilizing Convolutional Neural Networks (CNNs) and Genetic Algorithms (GAs), the proposed approach optimizes the rectification process, resulting in visually cohesive representations. Demonstrating the utilization of the VR lab across a range of situations, such as examining power transfer and creating control panels for water pumps in irrigation initiatives, the immersive setting enables students to delve into intricate systems. The performance of the proposed method was evaluated using various metrics, including mean squared error, peak signal to noise ratio (PSNR), structural similarity index (SSIM), and Fréchet inception distance (FID). the combination of deep learning algorithm specifically (CNN) and optimization algorithm specifically (Genetic algorithm (GA)) led to an increase in the accuracy of the rectified images where the average PSNR reached 23.98, SSIM was 0.8066, and FID was 18.72. Regarding the users' opinion about the generated environment by stitching and rectifying images, participants demonstrated consistent positive sentiments, with mean scores ranging from 3.65 to 4.03, all above the scale midpoint, and moderate variability indicated by standard deviation values ranging from 1.070 to 1.251, suggesting general favorability with some variation in responses. This experience empowers the users to gain insights and cultivate essential problemsolving abilities at a heightened level. Collaborative learning is facilitated, enabling students to engage in collaborative projects regardless of their physical location. Through the synthesis of image processing techniques and VR technology, this research contributes to the enrichment of educational experiences and the advancement of electrical engineering education.

Keywords: Virtual Reality, Image Stitching, Rectification Techniques, Immersive Learning, Virtual Lab

1 Introduction

Virtual reality (VR) technology has emerged as a transformative force with profound implications across various sectors, particularly in education [Lamb *et al.*, 2020]. In the realm of electrical engineering, VR's immersive and interactive capabilities hold remarkable promise, offering dynamic simulations, advanced education platforms, and intricate system visualizations [Vergara *et al.*, 2022]. Yet, the journey toward a truly seamless VR experience encounters a significant obstacle the rectification of irregular boundaries in stitched images [Ullah *et al.*, 2022]. These irregularities often arise when multiple images are fused together to construct panoramic or wide angle views within VR environments, leading to visual discrepancies, misalignment, and perceptual incongruities [Wahsh and Hussain, 2023]. The fidelity and credibility of the virtual world are paramount for electrical engineers who harness VR for design analysis, skill refinement, and exploration. The notion of rectifying irregular boundaries within stitched images arises as a pivotal means to alleviate these challenges[Jam *et al.*, 2021]. Navigating through the landscape of computer vision, this study examines existing rectification techniques and probes their suitability within the context of electrical engineering VR applications. A central tenet of this endeavor involves proposing a novel and customized rectification approach, tailored to the nuanced requisites of electrical engineering scenarios. The implications of rectifying irregular boundaries go far beyond mere technical enhancements. Engineers stand to gain from a seamless, true to life VR experience that unlocks the potential for interactive engagement with virtual models, precision simulations, intricate system visualizations, and the generation of insightful design optimizations. Furthermore, this rectified VR milieu paves the way for collaborative design efforts and remote collaboration, thereby elevating the efficacy and productivity of electrical engineering endeavors [Eswaran and Bahubalendruni, 2022]. In the pursuit of elevating VR within the realm of electrical engineering, rectifying irregular boundaries in stitched images stands as a linchpin, harmonizing the virtual and the real, and opening a gateway to enhanced exploration and innovation. In the subsequent sections, various aspects of our study will be delved into. Background information will be provided in Section 2, highlighting the significance of VR technology in education. Challenges encountered in creating VR environments, particularly focusing on image stitching and rectification, will be examined in Section 3. The experimental metrics employed for evaluation will be discussed in Section 4. In Section 5, the development of the virtual electric engineering lab will be detailed, emphasizing the use of image stitching and rectification techniques. The validation process, including user testing, will be covered in Section 6. Finally, Section 7 will conclude the paper, summarizing key findings and suggesting future directions.

2 Background

VR technology has garnered attention for its potential to enhance active learning and provide immersive experiences that facilitate deeper comprehension and knowledge retention within educational settings [Ma *et al*., 2023]. Research indicates that VR can establish interactive and experiential learning environments, enabling students to engage more actively and participate actively, thereby yielding improved learning outcomes[Marougkas *et al*., 2023]. Alongside investigating the educational benefits of VR, this assessment will delve into the potential challenges and limitations tied to its implementation in educational contexts. Factors such as cost limitations, technical prerequisites, and ethical considerations are critical aspects that warrant scrutiny to ensure the responsible and effective integration of VR technology into education [Suh *et al*., 2023]. Through an indepth exploration of the background and a comprehensive evaluation, this study endeavors to establish a robust framework for understanding the role and impact of VR technology in education. This initial analysis is crucial as it forms the basis, for discussions and discoveries. It will help us better understand the benefits and limitations of reality (VR) technology, in various educational environments. Acquiring VR technology for the study shows numerous problems that should be solved. Then the issue of the hardware requirements which includes compatibility should be attempted and also ways to make it affordable and available to all even in rural areas. Contribution of deepening the function of software to VR E-learning environments can be implemented by programming of process simulations, interactive content, multi release as well as performance improvement. Subject identification and development that would result in generating curriculums that are enjoyable for all interests and subject levels. Collaboration and dialogue among users play an important role in formation of usability and interaction structures which may direct towards the further development of the device and its success in the market. On the one hand, reliable and efficient technical support and guidance will be provided for teachers and learners through which teachers as well as learners will be able to use the technology better. While integrating the difficulties into VR education presents the question on the role of teacher, creator, and support personnel, and disruption it would implicate, it creates the necessity of concerted actions from tripartite parties including VR developers to make VR education a better experience.

2.1 VR Affordability

Computer simulations have been shown to be efficient teaching aids, particularly for the instruction of difficult subjects, according to [Petersen *et al*., 2020]. As a result, conventional simulation techniques have developed into immersive experiences like VR and augmented reality (AR), where students may interact with artificially intelligent characters or environments. A simulated world is created using computer technology in VR, which is increasingly used to teach a variety of courses, including coding, design, mathematics, geometry, the sciences, and engineering [Laseinde and Dada, 2023]. However, the typical student or instructor has not always had easy access to VR/AR. Although some contend that the development of the stereoscope in 1838 [Moncada, 2020], laid the foundation for VR/AR, goggles and gloves didn't begin to appear until the middle of the 1980s[Laghari *et al*., 2021]. These developments allowed for the development of immersive VR systems, like the CAVE idea, which let users move about a world that is projected into the walls around them. Historically, the cost of such equipment has been prohibitively high, but prices have significantly decreased over time. For instance, Google Cardboard, an affordable and simple headmounted display (HMD) made of cardboard, can accommodate regular smartphones [Walker *et al*., 2019]. This accessibility has made VR/AR experiences more affordable for institutions and individuals, and even more advanced headsets from companies like Oculus and HTC are becoming increasingly common in educational settings [Meccawy, 2022]. While hardware-related challenges for delivering VR/AR education have largely been addressed, there are still remaining issues concerning content, human-computer interaction (HCI), user experience (UX), and software applications[Fominykh *et al*., 2020].

2.2 Usability of VR

The progress of learning within virtual environments (VEs) introduces several issues regarding human-computer interaction (HCI) and user experience (UX) design that require careful consideration. One such issue is navigating and controlling photo realistic VEs (PVEs), which poses challenges in interaction design during the development of these experiences [Ijaz *et al*., 2022]. VR experiences typically provide users with a unique perspective, immersing them within the VE, unlike traditional 2D gaming environments where users observe and interact through an avatar within a window-like interface. Research [Stuart *et al*., 2022] explores the impact of visual realism on users' perception and interaction behavior in VEs, indicating that improved visual realism can enhance realistic behavioral responses. Similarly, [Zibrek and McDonnell, 2019] concludes that photo realistic avatars displaying realistic behaviors improve the quality of communication in immersive VEs. Realistic environments play a crucial role in maintaining learners' immersion and engagement in the VE during the learning process. The design of VEs must also consider learner autonomy. Two contrasting approaches to VE design in PVEs are guided pathways and free-roaming exploration. Traditional game designs often follow guided pathways, subtly directing players through a predetermined game map. However, VR experiences may benefit from a more open and exploratory approach, allowing learners to naturally and inquisitively identify and discover elements of the learning task. Research [Lakehal *et al.*, 2021] provides insights into supporting autonomy in virtual learning environments (VREs), emphasizing the importance of VREs in supporting reflection, self-awareness, collaboration with peers, and learner-centered learning environments. Additionally, [Gebhard *et al.*, 2022] highlights the significance of developing mechanisms to support group/shared experiences in VEs. Communication among group members in a shared VE introduces various HCI challenges, including presence, coordination, and collaboration issues. In group-based VR experiences, [Walker *et al.*, 2020] describes how epistemic scripts can enhance learning efficacy in virtual game environments. The inclusion of scripting provides structure and planning to the VE task, offering concrete pathways for learners. However, [Soares, 2023] warns against overly strict scripting, which restricts students' own constructions and hinders their capacity for collaborative learning, underscoring the importance of autonomy and collaboration in the learning experience. The impact and causes of VR induced sickness have been extensively studied, revealing that a significant portion of the population is susceptible to this phenomenon. VR-induced sickness poses a major obstacle to the wide-spread utilization of VR as an educational tool. Researches indicate that the relationship between visual velocity and visual angle in the VE is a primary factor influencing susceptibility to VR sickness [Mittelstaedt, 2020]. Therefore, VE designers must carefully consider experiences involving significant or prolonged exposure to motion-based visuals and recommend regular short breaks to mitigate potential discomfort. The evaluation of HCI and UX in VREs is a crucial process that VE designers must undertake to deliver effective learning environments. Various classical HCI approaches, including ethnography, have been successfully employed to observe and question users as they interact with VREs. For instance, [Blake and Gallimore, 2021] demonstrates the application of ethnography to understand the concept of presence in a virtual library setting. Researchers have also proposed using quantitative research methods to evaluate VREs, such as utilizing direct psycho physiological measures, which offer potential benefits and challenges [Kim and Kim, 2020]. The learning experience may be improved by VE designers by creating immersive and user-friendly environments that take these HCI and UX issues into account and apply the proper assessment techniques.

2.3 Related Work

VR technology is evolving, and this has sparked a rush of study into its potential as a teaching aid. This section examines a number of research that investigate the use of VR in educational settings, showing both its advantages and difficulties. Numerous studies emphasize the transformative impact of VR on active and experiential learning. [Chen *et al.*, 2021] examined the use of VR simulations to pro-pose a prototype of crime scene investigation with VR ap-plications [Chen *et al.*, 2021]. Similarly, [Menke *et al.*, 2019] identified VR's potential to create immersive learning environments that promote learner motivation and interactivity [Menke *et al.*, 2019]. Virtual laboratories, as demonstrated by [Laghari *et al.*, 2021], offer students opportunities to conduct experiments and develop practical skills through VR experiences chemical and biochemical engineering. Nonetheless, challenges related to VR implementation in education remain. Financial limitations are a common issue since VR systems sometimes need for substantial infrastructure expenditures in both hardware and software. Widespread adoption may also be hampered by technical requirements like network maintenance and capacity. Researchers like [Wylde *et al.*, 2023] have examined ethical implications, which include concerns like data protection and guaranteeing equal access to VR experiences [Wylde *et al.*, 2023]. Research shows that VR has the potential to improve cognitive engagement and memory recall. In their investigation into the use of VR simulations in medical education, Poulton and Conole (2019) showed how contextualized learning and knowledge application may be supported by VR experiences [Mystakidis, 2019]. The usefulness of VR-based learning for enhancing spatial abilities and problem-solving skills was also shown by Gugenheimer et al. [Gugenheimer *et al.*, 2017]. The most current research reviewed suggests that VR has enormous potential as a teaching tool. Researchers note the revolutionary advantages while also emphasizing the need to address issues with cost, technological needs, and ethical implications. This review contributes to a fuller understanding of VR's potential to transform learning experiences by offering insights into the rapidly changing VR landscape in education.

3 VR Environment Challenges

Rectifying uneven borders of stitched pictures is one of the major difficulties in developing VR settings. A poor VR experience can result from visual distortions, misalignment, and consistency issues that happen when several photos are stitched together to provide panoramic or wide-angle views for VR experiences [Tian *et al.*, 2022]. In order to provide a coherent and accurate picture of the scene, it is essential to fix distortions and misalignment when rectifing uneven borders in stitched images. This correction is necessary to guarantee that the VR environment properly depicts the real world and allows users to make judgement calls and observations while in the virtual environment. To deal with this issue, many correction methods in computer vision are now being investigated. By successfully adjusting erroneous boundaries in stitched pictures, these methods seek to increase the accuracy and dependability of VR settings

[Yan *et al*., 2023]. However, research is still being done to see if these methods are appropriate for VR applications in particular industries, including electrical engineering. Researchers have also suggested brand-new rectification methods that are customized to the distinct requirements of particular fields in order to further improve the production of VR environments. These methods ensure that the rectification process efficiently meets the demands of experts in sectors like electrical engineering by taking into consideration their unique requirements and obstacles. A seamless VR experience that closely resembles real-world settings may be created by overcoming the problems caused by the uneven borders of stitched pictures. This enables users to engage with virtual models, run precise simulations, see intricate systems, and get knowledge for design improvement.[Madni *et al*., 2019]. Additionally, improved VR settings provide opportunities for remote and collaborative design, boosting the effectiveness and productivity of several jobs in a variety of industries, including electrical engineering. In the subsequent sections, the specific challenges posed by irregular boundaries of stitched images will be discussed, explore existing rectification techniques in computer vision, assess their suitability for VR applications in electrical engineering, and propose a novel rectification technique tailored to meet the unique needs of the field. Through this research, the aim is to overcome the challenges associated with irregular boundaries and provide a solid foundation for creating high quality VR environments in various domains. The subsequent sections will delve into the construction of a comprehensive laboratory environment through the utilization of cutting-edge technologies. This exploration will encompass the seamless integration of VR elements, unveiling the amalgamation of diverse tools, immersive visuals, and interactive interfaces. A detailed insight will be provided into the meticulous design considerations, technological implementations, and usercentric features that collaboratively shape an immersive and educational laboratory experience.

3.1 Image Stitching

A panoramic or wide-angle image is produced by combining several overlapping photos using image stitching, a fundamental computer vision technique. To remove seams and provide a continuous, seamless scene, this procedure aligns and blends several pictures. In VR contexts, where it is widely used, image stitching is essential for creating immersive visual experiences. Image stitching is used in VR to smoothly combine photos taken from different views into a spacious and unified virtual scene. This method makes it possible to produce engaging and realistic VR scenarios, increasing user engagement and immersion. Additionally, picture stitching makes it easier to create wide-angle images, which are essential for giving consumers a comprehensive and panoramic VR experience. The resulting immersive environment allows for exploration and interaction with the virtual world from various perspectives, as well as improving the user's impression of depth and space. The most common solution to create a 360 degree environment is by using a 360 degree camera. However, this kind of cameras suffer from multiple challenges. The 360-degree format can suffer from significant barrel distortion, detracting from the visual quality of the immersive experience. Additionally, its suitability is limited in indoor locations and low-ceiling rooms due to space constraints, which may restrict the viewer's freedom of movement and diminish immersion. Furthermore, managing parallax effectively is crucial with 360-degree cameras, as discrepancies in perspectives captured by multiple lenses can lead to visual inconsistencies and distortions[Shi *et al*., 2019]. As a result, image stitching and rectifying serves as a cornerstone for achieving the visual richness and realism that define modern VR applications, contributing significantly to the success of VR-based educational and experiential platforms. **Figure 1**, **Figure 2**, **Figure 3**, show the process of stitching images was taken sequentially by detecting the important features.

3.1.1 Feature Detection and Feature Matching

The Scale Invariant Feature transformation (SIFT) algorithm, initially proposed by David Lowe in 1999 and later improved in 2004 [Lowe, 2004][Xu *et al*., 2016], plays a significant role in the detection of local features, commonly known as "key points," within an image. The SIFT algorithm comprises several distinct steps, which are outlined below:

- Key point detection, also referred to as feature point detection.
- Key point localization.
- Orientation assignment.
- Feature descriptor generation.

By identifying key points in images, SIFT extracts invariant descriptors that encapsulate essential information about the local image structure. SIFT is a powerful tool for applications like picture registration, object identification, and panoramic image stitching since these descriptors make it easier to recognize the same item or scene in several photographs. The SIFT technique is remarkably useful in the context of VR situations. The building of immersive VR landscapes is supported by its capacity to correctly find and match elements in photos, resulting in seamless and coherent panoramic views. Because of its flexibility and resistance to a variety of imaging settings, SIFT is a vital tool in the toolbox of methods that improve the visual quality and realism of VR experiences. The descriptors are compared, and the feature matching algorithm is used to find the closest match in order to build correspondences between features in two images. In order to choose the matching model with the greatest number of inliers and concurrently weed out any outliers that deviate from this model, the RANSAC algorithm is used. The associations between these pairings are represented by a homography matrix that is constructed from the matching pairs of feature pairs in the pictures. Based on this homography matrix, the rotation matrix and focal length are then calculated for each picture [Lowe, 2004]. The closest neighbors are determined in order to guarantee an equal distribution of important details across both photos. It is important to keep in mind that, in some circumstances, noise or other factors may cause the second-closest match to show a closeness identical to the first match. In these cases, the nearest-to-second-nearest distance ratio is used [Xu *et al.*, 2016].

Figure 1. Two overlapped images

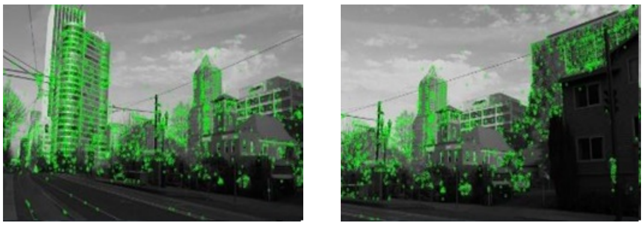

Figure 2. Extreme points of the overlapped images

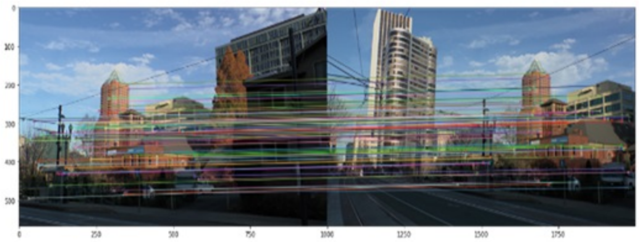

Figure 3. Features Matching

3.1.2 Homography based warping and blending

An image processing method called homography-based warping allows for the conversion of an image between several coordinate systems[Zhang *et al.*, 2020] [Lee *et al.*, 2020]. This transformation is based on the idea of homography, which uses a matrix to show how two images of the same scene taken from different angles relate to one another. The following steps are involved in the homography-based warping process:

- Recognition of similar spots in the two photos. These points are places, like a building's corners or a line's junction, that are present in both photographs at the same spot.

- The homography matrix is calculated using these related points. The transformation that converts points from one picture to their equivalent positions in the other is described by this matrix.Homography-based warping finds widespread applications in image stitching, panoramic creation, and image registration.

It is particularly advantageous for aligning images captured from different perspectives, as it enables the correction of perspective distortion and alignment of features between the two images [Zhang, 2020] [Ravi and Gowda, 2020]. The outcome is a stitched image with a wider field of view, treated as a single cohesive image. However, challenges such as visible seams or ghosting may arise due to exposure differences or the presence of moving objects in the overlapping region. These factors significantly impact the quality of the stitched image, as illustrated in **Figure 4**.

$$\begin{bmatrix} \bar{X} \\ \bar{Y} \\ 1 \end{bmatrix} = H \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} * \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} \tag{1}$$

Figure 4. Two stitched images with different exposure

Figure 5. Stitched, warped, and blended image

3.2 Image Rectifying

After examining **Figure 5**, it becomes clear that the re-sulting image shows irregular boundaries due to the warping process used to address any stretching or distortion that might have occurred during the image stitching. As men-tioned earlier in this research, certain applications that uti-lize image stitching techniques require users to accept irregu-lar boundaries [Zhao *et al.*, 2021]. To solve this problem, various solutions have been proposed to obtain rectangular boundaries. These solutions range from simple approaches like cropping the image to more complex deep learning algorithms that aim to eliminate irregular boundaries [Deng *et al.*, 2018], known as image rectifying. However, cropping the image to make it rectangular can result in the loss of important content, which could be relevant to the end user. Therefore, this technique is not recommended. In the fol-lowing sections, we will discuss some of the proposed meth-ods for achieving rectangular stitched images.

3.2.1 Content-Aware Fill Rectifying

This approach to image rectifying heavily depends on the content of the image with irregular boundaries. As described by [Song *et al.*, 2021], the method starts by identifying the longest segment of the boundary that requires filling. The subsequent step involves calculating the seam, which determines the highest contour of the sub-image corresponding to the longest boundary. Then, a one-pixel shift in a consistent direction is applied to every pixel. By calculating the next seam and doing the earlier stages again, this procedure is repeated. The technique of content-aware picture correcting, which uses the idea of seam cutting for localized warping, is shown graphically in **Figure 6**. This technique has a notable

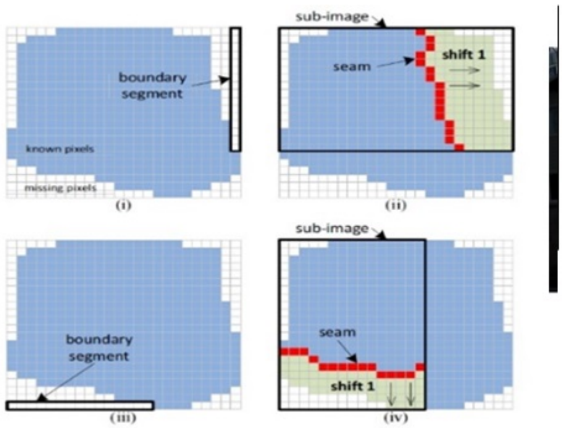

Figure 6. Local seam carving approach

drawback in that it is primarily applicable to photos where seams can be effectively copied. This limitation becomes particularly evident in images that contain regular patterns in the seam region, as highlighted by [Song *et al.*, 2021]. While seam carving is a powerful method for content-aware image resizing, it may not yield optimal results for images that feature sharp edges or intricate details, such as textual elements or facial features. When applied to such images, the seam carving technique can lead to undesirable outcomes, where the overall quality of the image may deteriorate significantly. For instance, removing seams from certain regions can result in noticeable blurring or distortion, compromising the integrity of the visual content. This is especially problematic in photographs where precision and clarity are essential, as in the case of portraits or images containing detailed graphics. To further illustrate the capabilities and limitations of this technique, **Figure 7** presents two images that have undergone a series of processes, including stitching, blending, and warping. These operations aim to create a seamless transition between various image segments. On the other hand, **Figure 8** demonstrates the rectification of irregular boundaries achieved through the use of the Content-Aware Fill technique. This method not only addresses the issues of seams but also effectively minimizes visible distortions that can detract from the overall aesthetic appeal of the image. Upon close inspection, the distortion that results from inadequate seam removal becomes readily apparent, highlighting the need for careful consideration when utilizing these image processing techniques.

3.2.2 Local and Global Warping Rectifying

According to the statement, the suggested alternate method for correcting visual distortion combines local and global warping techniques. This technique was created by by

Figure 7. Input images after stitching

Figure 8. Image rectifying based on local warping via seam carving

[He *et al.*, 2013], and it integrates ideas from earlier research on picture completeness, image retargeting, and image warp-ing. The process of "image completion" is creating panoramic pictures by synthesizing the missing pieces from ma-terial in other, known places. Using a technique called seam carving, which intelligently resizes photos by taking into account the relevance of content along the seams, the local warping stage in this method is locating and eliminating seams from the image. The method ensures correction without adding new distortions by using seam cutting for local warping. The global warping stage improves picture rectification by using a mesh-based methodology. With mesh-based warping, the picture is projected onto a grid of vertices and edges that may be adjusted to distort it. The deformed picture is overlaid with a mesh in this approach, which is then twisted backward to create a mesh that fits the input image. Any lingering distortions that the local warping phase did not eliminate can be addressed with the aid of this technique. Mesh optimization, the last phase in this process, is modifying the mesh's vertices and edges to produce a rectangular border picture. Mesh optimization may be accomplished using a variety of methods, including geometric restrictions and energy minimization. According to [Nie *et al.*, 2022], the local and global warping method is computationally intensive due to its two-step process. The study also notes that the proposed energy function can only handle linear structures, as shown in **Figure 9**. However, in panoramas with an Extended Range Projection (ERP) for-mat, straight lines may appear curved. To address this limi-tation, [Wang *et al.*, 2021] introduced introduced a line-preserving energy term in addition to the geodesic-preserving energy term. Although this improvement en-hances the rectification, the geodesic lines cannot be accu-rately detected from the stitched image, and the improve-ment is primarily observed in the panorama itself. Figure 9 illustrates rectifying the irregular boundaries by using the Local and Global Warping technique and it can be easily seen the distortion.

Figure 9. The distortion after applying the local and global warping technique

4 Experimental metrics

The experimental measurements used to evaluate the re-sults of the paper include Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), and Fréchet Inception Distance (FID), which are widely used in image processing. PSNR is calculated as follows:

$$PSNR = 10 \times \log_{10}\left(\frac{MAX^2}{MSE}\right) \quad (2)$$

where MAX is the maximum possible pixel value and MSE is the mean squared error between the original and reconstructed images. Higher PSNR indicates better image quality. While SSIM is calculated as follows:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (3)$$

Where $_x$ and $_y$ are the mean pixel values of x and y, $_x$ and $_y$ are their standard deviations, $_{(}x, y)$ is their covariance, and $C1$ and $C2$ are small constants to avoid division by zero. Higher SSIM indicates better perceptual quality. Regarding FID, it can be calculated as follows:

$$FID(x,y) = \|\mu_x - \mu_y\|^2 + \mathrm{Tr}\left(\sigma_x + \sigma_y - 2\left(\sigma_x\sigma_y\right)^{\frac{1}{2}}\right) \quad (4)$$

where x and y are the feature representations of the generated and real images, respectively, $_x$ and $_y$ are their mean values, $_x$ and $_y$ are their covariance matrices, and T_r is the trace operator. Lower FID indicates better image quality. Overall, these metrics provide a comprehensive evaluation of the quality of the generated images and help to validate the effectiveness of the proposed method in the paper.

4.1 Image rectifying based on Deep Learning

Deep learning-based image rectification techniques offer numerous advantages over traditional solutions. Firstly, they excel in handling a wide range of irregular boundary patterns, including intricate and nonlinear distortions that simpler methods like cropping or geometric transformations struggle to address [Nie *et al*., 2022]. By capturing complex relationships and patterns within the image data, deep learning models exhibit enhanced precision and flexibility when rectifying irregular boundaries. Moreover, deep learning-based solutions demonstrate adaptability and generalization across various image content types. They effectively rectify images containing sharp edges, fine details, and text, which often pose challenges for tradition-al methods. In contrast, alternative techniques like seam carving or mesh-based approaches may introduce blurring, distortion, or loss of crucial content in these areas, whereas deep learning models can learn to preserve such details during the rectification process [Yen *et al*., 2017] . Additionally, the accuracy and performance of deep learning models can be further improved through transfer learning. By fine-tuning pretrained models on large-scale datasets specifically for image rectification in VR learning and education environments, transfer learning leverages the knowledge and representations acquired from diverse visual data, resulting in enhanced rectification outcomes. A research conducted by [Wahsh and Hussain, 2023] to study that extensively explored the rectification of irregular boundaries in stitched images using deep learning tech-niques specifically (CNN) and optimized by using Genetic algorithm. The paper encompassed a comprehensive comparison of various approaches, encompassing both traditional methods and deep learning-based solutions, in the context of image rectification. The outcomes demonstrated the remarkable precision and adaptability of deep learning in rectifying irregular boundaries. Through leveraging the capabilities of deep neural networks, the proposed method proficiently acquired intricate mappings and extracted complex patterns from the image data. Consequently, the deep learning model achieved superior rectification outcomes by accurately preserving essential image content, surpassing the performance of traditional techniques. The research findings strongly highlight the substantial benefits of deep learning in addressing the challenges associated with irregular boundaries in stitched images, firmly establishing it as the preferred and superior method for attaining rectification results of exceptional quality. **Figure 10** shows a comparison between the proposed approach and other related works, the results demonstrate that the proposed approach in this study are outperformed other approaches. The performance of the method was evaluated using several metrics, including peak signal-to-noise ratio (PSNR), structural similarity index (SSIM), and Fréchet inception distance (FID). The results indicate that the proposed method achieved a PSNR of 23.98 dB and an SSIM of 0.81. These results demonstrate the effectiveness of the proposed method in accurately rectifying images, even when they have complex shapes and orientations.

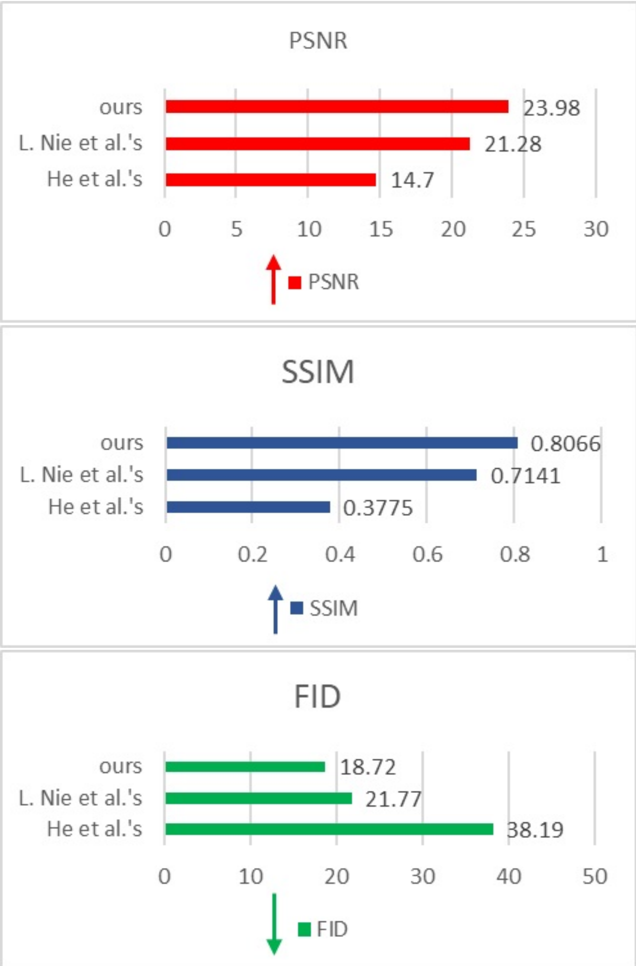

Figure 10. PSNR, SSIM, and FID Metrics of The Proposed Approach Compar-ing to Other Related Work

CNN are a pioneer in the field of image rectification. CNNs, which make use of deep learning, have an unmatched ability to recognize patterns, features, and anomalies in images. They can process and analyze images at different levels of abstraction due to their hierarchical architecture, which also enables them to intelligently alter pixels based on learned attributes to correct uneven borders. The task of aligning and merging images flawlessly is now possible with a new degree of precision due to this revolutionary technology, producing results that are distortion-free and visually precise. Additionally, a cutting-edge method for image rectification is provided by genetic algorithms. These algorithms iteratively improve picture transformations to optimize alignment and rectification. They were inspired by the concepts of natural evolution. Through the use of a population-based search strategy. The vast solution space is explored using genetic algorithms, which eventually con-verge on the ideal rectification settings. This evolutionary methodology provides robustness in addressing sophisticated image distortions in addition to adapting to detailed anomalies. The process of composing coherent and aesthetically acceptable compositions from individual photos is being revolutionized by the combined integration of CNNs and Genetic Algorithms. **Figure 11** illustrates the sequential progression undertaken during the establishment of the VR Lab starting with capturing sequential images, stitching them and rectifying the borders to obtain panoramic image and, build the VR environment and finally loading it to the VR platform.

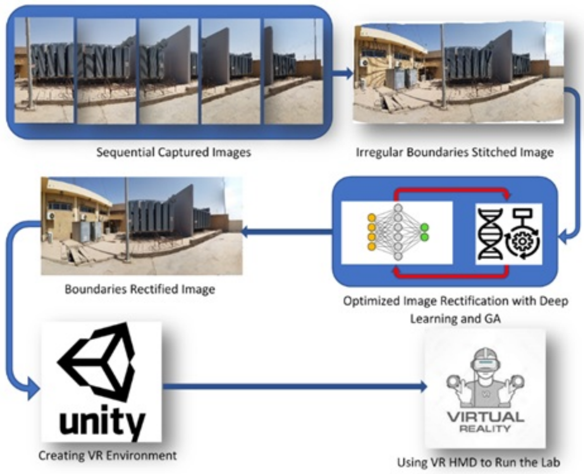

Figure 11. The distortion after applying the local and global warping technique

5 Virtual Electric Engineering Lab: Leveraging Image Stitching and Rectification

In the realm of electric engineering education, the integration of advanced technologies is reshaping traditional learning approaches. VR environments present a promising avenue to enrich educational experiences, enabling students to interact with complex systems, perform experiments, and gain practical insights within a simulated yet immersive setting. This section explores the integration of image stitch-ing and rectification techniques in a virtual electric engineering laboratory, enhancing the authenticity and effectiveness of the educational environment. In order to produce panoramic vistas, the virtual electric engineering laboratory makes use of image-stitching methods. A complete and seamless atmosphere is created by combining photographs taken from various viewpoints. Through the use of this approach, students may explore various areas of the lab, mimicking a real experience that goes beyond what is possible in a typical classroom. The end product is a visually stimulating environment that encourages interesting interactions with various tools and parts. A critical phase in designing a seamless VR experience is rectification. To provide a seamless transition between combined pictures, it fixes any imperfections that may appear during image stitching. The rectification procedure straightens and corrects pictures to get rid of distortions and misalignment by using genetic algorithms and CNN. Students engage with a smooth and aesthetically correct virtual world thanks to this thorough approach. The use of picture stitching and rectification in the virtual electric engineering lab has several educational benefits. Through virtual exploration of intricate electrical systems, students can get a deeper comprehension of theoretical ideas. The risk-free environment of the immersive environment encourages exploration and observation without being physically constrained. Additionally, the virtual aspect of the lab allows for remote access and collaborative activities, providing a platform for inclusive learning. Images of electricity transmission lines, substations, transformers, and other pertinent elements are used to build the VR lab. In order to generate panoramic panoramas that accurately depict real-world power distribution conditions, these photographs are meticulously stitched together and corrected. Students may move around the virtual environment, interact with components, and learn about power flow, load distribution, and efficiency thanks to a user-friendly interface. The example of stitching and rectification of numerous consecutive photos in **Figure 12** below illustrates how stitching and rectification techniques can be used to provide a seamless panoramic view.

Figure 12. A Sample of multiple sequential images stitching and rectifying

5.1 Image Acquisition and Camera Setup

The photographs used in this study were taken as part of the west of Baghdad's Abu-Ghraib irrigation project. A particular camera set-up was used to achieve precise and consistent findings. The Nikon 5100 was chosen because of its capacity for taking high-resolution pictures. To ensure stability and reduce alignment changes, the camera was set on a tripod for taking these pictures. A series of photos was taken with purposeful overlapped sections in order to create panoramic views by stitching and rectification. The exact alignment of the photos during the following stitching procedure is made possible because to this overlap, allowing for the construction of seamless panoramic vistas. For the stitching and rectification methods to be accurate, camera calibration was essential. The camera underwent a calibration procedure before taking the pictures in order to correct lens aberrations and inherent characteristics. In order to ensure exact alignment and reduce aberrations in the final stitched pictures, this calibration phase was crucial. The dimensions of each individual picture used in this study are 4032 width by 2268 high, which provides the essential detail for precise stitching and correction procedures. These dimensions were thoughtfully chosen to strike a compromise between the need for resolution and computational effectiveness, eventually helping to provide the excellent panoramic results obtained in this study.

5.2 Creation of the Immersive Irrigation Lab

The advanced VR laboratory described in this section was meticulously built to investigate the control and functioning of water pumps in irrigation projects. This immersive platform, which makes use of the Unity game engine, enables engineering students to visually interact with control panels, pumps, and full irrigation systems, giving them a thorough grasp of the functioning and operation of the gear. This VR lab's key feature is the use of photos taken from real irrigation facilities, such as control panels, pump stations, and sizable irrigation fields. These raw images are ingeniously stitched, rectified, and integrated into the Unity environment, resulting in panoramic scenes that replicate real-world irrigation setups with remarkable accuracy. This fusion of technology creates an immersive experience that allows students to virtually step into the shoes of irrigation engineers.

5.3 Unity Game Engine and Interaction

Capitalizing on the potent capabilities of the Unity game engine, students are transported into an intricate virtual realm that unveils the inner workings of electrical components within an irrigation system. This transformative experience seamlessly merges intuitive controls with meticulously designed elements, mirroring the real-world actions that are crucial for the efficient operation of these systems. While the scope of interaction remains confined to the sphere of observation and exploration, the immersive quality of this encounter is unmatched. Within this immersive landscape, students aren't mere observers; rather, they emerge as active participants in a virtual arena that meticulously replicates the presence and ambiance of an authentic electrical environment within an irrigation system. Although the actions available to students may be constrained, the depth of sensory engagement they experience is unparalleled. Unity's cutting-edge physics and animation capabilities serve as the foundation for this simulated reality, ensuring that every interaction resonates with an authenticity that bridges the chasm between theoretical comprehension and practical application. As students venture into this carefully crafted digital expanse, they are encouraged to absorb the minutiae of their surroundings—the nuanced details of electrical components, textures, and visual intricacies meticulously curated to echo the subtleties of an actual electrical setting. While interaction occurs within the bounds of observation, Unity's technological prowess elevates this interaction beyond mere visual engagement, encompassing a profound sensory experience. This harmonious blend of technology and pedagogy extends the frontiers of conventional learning, transforming it into a dynamic landscape where students aren't just passive learners but become co-creators of an augmented reality. Through the seamless orchestration of Unity's capabilities, the virtual environment transcends a mere conduit of information to become an essential junction where theoretical concepts intertwine with experiential understanding. In essence, the incorporation of the Unity game engine within the virtual electric engineering lab doesn't just impart knowledge; it encapsulates students in an educational odyssey. Within this digital domain, students not only witness but also tangibly sense the very essence of electrical components within an irrigation system, forging a connection that adeptly bridges the chasm between theoretical studies and real-world practicality. Inside the VR lab, students immerse themselves in the world of irrigation control panels, where they can interact with physical buttons, toggles, and knobs. Through these interactions, students witness the cause-and-effect relationships between their actions and the system's responses. Simulated scenarios, such as starting and stop-ping pumps, altering water flow rates, or troubleshooting common issues, empower students to develop a profound understanding of control panel logic and its real-world implications. **Figure 13** shows the visual insights from the Lab environment.

5.4 Educational Benefits Derived

The power transfer analysis VR lab offers a wealth of educational advantages and transforms how students view and interact with intricate electrical settings. This cutting-edge platform goes beyond conventional teaching strategies by providing a trip that immerses pupils in areas that are frequently inaccessible. Students participate actively in the complex electrical landscapes they encounter in this virtual world rather than simply viewing them as spectators. Through this immersive learning environment, students will be able to explore these difficult areas outside of the constraints of textbooks and traditional teaching techniques. The VR lab offers a special method for understanding difficult ideas by using a language of visuals and sensory engagement. Students are able to understand the interconnections of different components within power systems because to this tactile involvement. This approach fosters a deeper comprehension that goes beyond theoretical knowledge and enables students to have an emotional connection to the subject. Additionally, this immersive learning strategy promotes the development of crucial problem-solving abilities. Students face difficulties that are similar to real-world situations as they go through these complex virtual worlds. Students develop their critical thinking and analytical skills by taking on these difficulties inside the secure boundaries of the virtual environment, better preparing them for the complexity of real-world applications in the area of electrical engineering. The potential of the VR lab to encourage a sense of shared presence and teamwork among students is its actual power. Due to the fact that this digital space is devoid of physical boundaries, students from diverse areas may come together and explore these virtual lands as a group. Students are exposed to a variety of viewpoints and experiences via group projects and de-bates, which deepens their grasp of the material and raises their level of global consciousness. In conclusion, the power transfer analysis VR lab is more than just a teaching tool; it is an example of innovation that enables students to go beyond their physical limitations and experience the complex situations that are at the core of electrical engineering. This platform creates a generation of engineers that are not just smart but also sensitive to the practical nuances of their area by activating their senses and encouraging cooperation. For a comprehensive exploration of the laboratory environment and its interactive functionalities, readers are encouraged to access the following link: https://drive.google.com/file/d/1E3AoJ7WY-jBM3TUXMdU1pdXDaq6eMpqi/view.

6 Laboratory Validation

Laboratory validation is an integral part of scientific research because it enables researchers to test ideas, develop techniques, and verify results under controlled conditions. However, the results aren't always as trustworthy, repeatable, or accurate as they seem. It's typically essential to ensure results can be applied to the real world and expanded upon when they're analyzed in larger settings. Being able to fine-tune variables and minimize outside distractions is one of many perks to this kind of work, and scientists often can't live without this many levels of precision, especially when the potential consequences of any mistakes are serious. And this kind of research is said to be something of a self-policing. It lets you kill practically all discrepancies (including confounding variables) before anyone notices them. By setting very clear rules for validating test results like this, researchers are giving future experiments (or practical applications) a solid foundation. It not only asks for higher standards for individual studies, but it also raises the bar for scientific research as a whole. For this research, the validation is crucial to ensure that the created environments are precisely stitched, rectified, and built for the VR plat-form and free of any kind of distortion. Accurate stitching and rectification of images are crucial to rendering VR labs that will look immersive and realistic. In this context, electricity engineering is of special importance. Correct stitching guarantees seamless blending between images and therefore improves the quality. Rectification straightens the warps, building up a uniform representation that depends on it for a complete understanding of complex systems. These techniques, for example, scan intricate parts and have virtual labs enabling students to interact with the same components in VR, ensuring students' accurate perception and engagement; hence, the virtual learning experiences are effective. Generally, the use of image processing approach-es to be specific is significant to the development of realistic and educational VR tools.

6.1 Evaluation Using the Technology Acceptance Model (TAM)

In 1989, Davis proposed the Technology Acceptance Model (TAM) [Davis *et al.*, 1989], and it has since become a widely used paradigm for evaluating technology acceptability in many settings. The TAM explores how people's attitudes and intentions toward using a technology system impact two factors: perceived ease of use (PEOU) and perceived usefulness (PU). In this vision, the TAM is a "systematic and comprehensive approach to ensuring the feasibility and utility of an experimental lab within or provided alongside a research proposal and associated construction" the agency writes in its call for proposals. In other words, researchers and practitioners who'd use the lab for something will know just how apt, rigorous, and user-friendly it is on all the metrics they will hopefully request. The primary objective of implementing TAM is to get insight into how in-

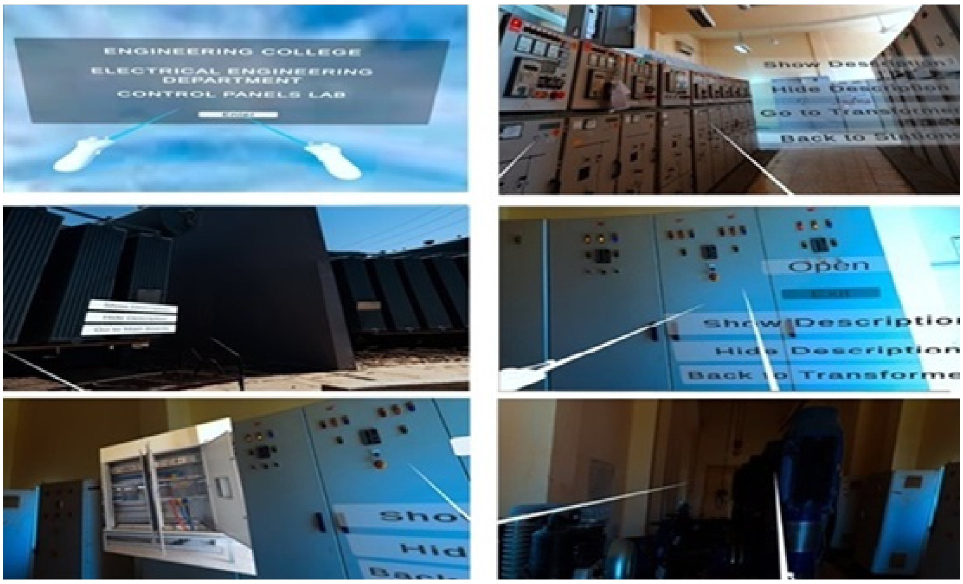

Figure 13. Visual Insights from the Lab Environment

dividuals perceive the laboratory's practicality and use. It is by these measures that the laboratory's intended users will be evaluated. Finding out how people feel about it and what they want to do with it might be aided by conducting surveys and gathering empirical data. By including TAM in the assessment framework, it is not only a systematic approach but also the ability to ground the proposed study in well-established theoretical frameworks, increasing the generalizability and relevance of the results. **Figure 14** shows the technology acceptance model.

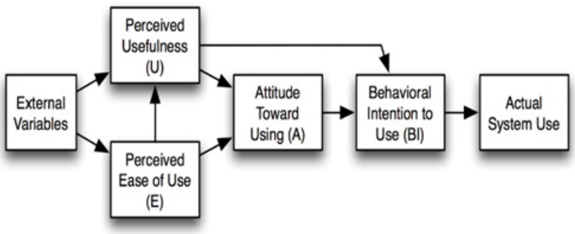

Figure 14. Technology Acceptance Model

6.2 Data Collection

In the methodological framework used for this research, the main data collection instrument was a well-crafted questionnaire. By employing Google Forms, the accessibility and efficiency of a device have been seamlessly integrated into every question. To this end, the questionnaire was meticulously designed to incorporate each of the myriad aspects composing this research objective. A secure link was produced and sent directly to the email addresses of target populations through systematic methods such as popular social media like Facebook, WhatsApp, and Telegram. The dedicated effort resulted in 314 questionnaires being distributed to a diverse range of respondents. Given the diverse languages spoken among this receiver group, the questionnaire was carefully translated into both English and Arabic; the aim is not only to foster all-inclusiveness but also to invite far more responses. The survey period extended over a month, meaning respondents had ample time to consider their replies at leisure. Notably, the data collection stage proceeded scrupulously in August and September 2023 in the careful examination of the collected data, 314 questionnaires complied in full with the research guidelines and were practically usable. On this note, all suspect items have been identified and rectified meticulously, thus ensuring the correctness and reliability of every data element. So, the study provides a total of 314 responses with a 100 percent return rate an enviable mark showing how thoroughly prepared and meticulously executed is its data collection process. It is worth mentioning that the questionnaire utilized a Likert scale to gauge participant responses, providing a structured framework for evaluating perceptions and attitudes efficiently and comprehensively where (S.D) stands for strongly disagree, (D) is Agree, N is neutral, (A) is agree, and (S.A) is strongly agree. Table 1 shows the questionnaire items utilized in this research.

6.3 Validation Results

The validation of an experimental laboratory holds paramount significance in the realm of academic research and practical applications. In the journey of scientific inquiry, the laboratory serves as the testing ground, a crucible for hypotheses, and a space where innovative ideas are brought to life. However, the effectiveness and credibility of this crucial research environment heavily depend on its validation. The process of validation involves not only the establishment of its functionality but also the assurance that the experimental setup faithfully represents the real-world scenarios it seeks to mimic. This section provides the insight on the vital necessity in validating of laboratory constructed for the undertaken approach, versus through a survey outlook. Proving

Table 1. Questionnaire Items

No.	Questionnaire items
	Demographic Information
1	What is your age?
2	What is your gender?
3	What is your current academic year?
4	Have you used virtual reality (VR) technologies before?
	Perceived Usefulness
5	Using the VR lab can help me understand complex electrical engineering concepts.
6	The VR lab can enhance my ability to apply theoretical knowledge to practical
7	The VR lab's simulations are relevant and valuable for my electrical engineering studies.
8	The VR lab improves my overall learning experience in electrical engineering.
9	I believe the VR lab is an effective tool for deepening my understanding of specialized topics within electrical engineering.
10	The VR lab contributes positively to my grasp of real-world applications in electrical engineering.
11	I find the VR lab's content to be directly applicable to my academic goals in electrical engineering.
	Perceived Ease of Use
12	The VR lab's user interface is easy to navigate.
13	I quickly adapted to using the VR lab's controls and interactions.
14	Learning to use the VR lab was straightforward.
15	I feel confident using the VR lab's technology without difficulties.
16	The VR lab's interface is intuitive and user-friendly.
17	Interacting with the VR lab's simulations feels natural and comfortable.
	General Acceptance and Intent to Use
18	I am likely to allocate additional time to use the VR lab for my electrical engineering studies.
19	I am likely to allocate additional time to use the VR lab for my electrical engineering studies.
20	I am open to integrating the VR lab into my regular study routine.
21	The VR lab is a valuable resource that complements my other learning materials.
22	I am willing to invest effort in exploring various aspects of the VR lab to maximize its benefits.
23	I would recommend the VR lab to other electrical engineering students for their studies.
24	I can see myself relying on the VR lab for a substantial portion of my electrical engineering coursework.
	Overall Attitude
25	I am enthusiastic about the opportunity to use the VR lab for my electrical engineering studies.
26	I have a positive outlook on how the VR lab can enhance my performance in electrical engineering courses.
27	The VR lab excites me as a tool for expanding my understanding of complex electrical engineering concepts.
28	My overall impression of the VR lab is favorable.
	Technology Experience
29	I am confident in my ability to use technology effectively for learning.
30	I have experience using VR technologies for educational purposes.
31	I am comfortable using various digital tools and software.
32	I am familiar with the general principles of virtual reality technology.
33	I consider myself capable of quickly adapting to new technology-driven learning environments.

the validity and reliability of the lab confirms that the epistemological ground on which academic activity and practice are predicated is trustworthy and therefore supplying exhaustive facts from experiments with stronger grounds. The chapter of the validation process is unskippable in a mission to contribute nontrivially to the sphere of knowledge and addressing real-life challenges effectively. PEOU is addressed to the effectiveness of attitude, where users' perceptions on how easy it was/is using a technology are measured along with possible aspects like ease of learning and navigation. Alternatively, the PU measures users' perceptions regarding technology utility in achieving better job productivity or task performance. The set of the common questions used in TAM, which allows for assessing these constructs, is generic and can be applied to other technological areas. These questions are commonly adapted to suit the peculiarities of the technology under study, which makes this instrument quite flexible for analyzing user acceptance in various technological settings. This method however does not only enable an initial assessment of adoption but also serves to suggest signaling solutions, design, and user experience for implementation. Within the setting of the VR Electric Lab, the sample population being targeted who would be participants in TAM studies consists of students, educators, and professionals in electrical engineering and power systems fields. Involving those closely associated with the subject matter may con-tribute to understanding the acceptance of VR technology in a more detailed way, especially in the case of electric labs. Students represent the primary end-users, providing valuable perspectives on the ease of use and perceived usefulness of the VR electric lab for educational purposes. Educators and professionals, with their expertise in the field, offer insights into the technology's practicality and relevance for enhancing learning outcomes and professional development. This targeted sample ensures that the TAM assessment is not only comprehensive but also aligns with the intended audience of the VR electric lab, offering tailored insights for refining the technology's design and implementation within the realm of electrical engineering education. In the subsequent sections, a detailed analysis is explored to obtain a full comprehensive of the targeted sample and their opinion about VR laboratory.

6.3.1 Demographic Information of Survey Responses

The demographic information of the respondents provides a comprehensive overview of the participants' characteristics. It reveals that out of the total number of respondents, 209 individuals, which accounts for 66.6%, are male, while 105 respondents, or 33.4%, are female. This distribution highlights a predominance of male respondents in the study. Furthermore, the data illustrates the age breakdown of the respondents. A relatively small group, 26 individuals (8.3%), fall within the age range of 18 to 21 years. This is followed by 52 respondents (16.6%) who are between the ages of 22 and 25. The largest proportion of respondents, 124 individuals (39.5%), belong to the age group of 26 to 30 years, indicating a strong representation of young professionals or students in this cohort. Meanwhile, 112 respondents (35.7%) are over 30 years of age, showing a significant portion of more mature participants. A total of 124 (39.5%) of the respondents are in the group of ages 26-30 years. While 112 (35.7%) are older than 30 years. n terms of academic standing, the demographic data reveals that 19 respondents (6.1%) are in their first year of study, while 15 respondents (4.8%) are in their second year. The third-year students are represented by 43 respondents (13.7%). However, the largest group comprises 112 respondents (35.7%) who are in their fourth year, indicating that a substantial portion of the sample is nearing the completion of their academic programs. Additionally, 125 respondents (39.8%) fall into the ”other stages” category, which could include students at different educational levels or those pursuing advanced or specialized studies.

When asked about their prior experience with virtual reality (VR) technology, the responses revealed a diverse level of exposure. A total of 161 respondents (51.3%) indicated that they have used VR technology before, demonstrating a significant familiarity with this emerging tool. On the other hand, 98 respondents (31.2%) reported that they had never used VR technology, suggesting that a third of the participants were relatively new to the experience. Furthermore, 55 respondents (17.5%) provided a more uncertain answer, indicating that they may have used some form of VR technology, though they were not entirely sure of their experiences.

The survey consisted of a series of statements to which participants were asked to express their level of agreement on a scale. The analysis of the survey responses involved the calculation of both the mean and standard deviation for each statement. It is worth mentioning that a video was uploaded to Google Drive to show the way how the lab is working as well as the APK file of the application for those who own the VR HMD to try it by themselves.

Figure 15, **Figure 16**, **Figure 17** and **Figure 18** shows the representations of demographic information

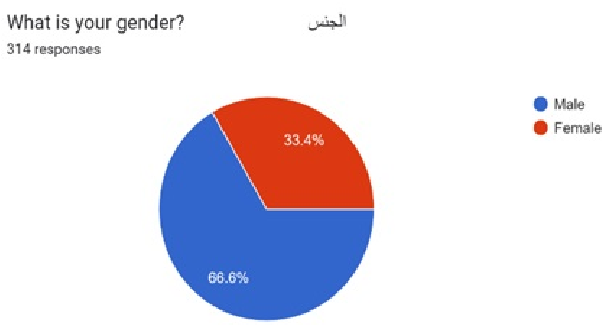

Figure 15. Demography information (Gender)

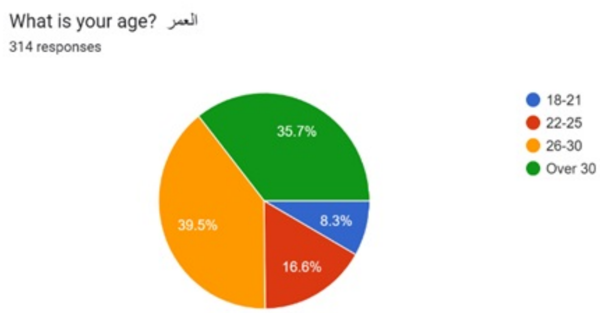

Figure 16. Demography information (Age)

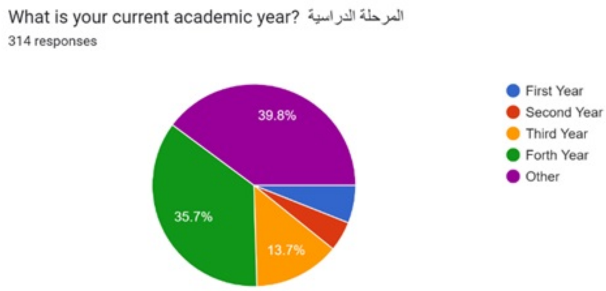

Figure 17. Demography information (Stage)

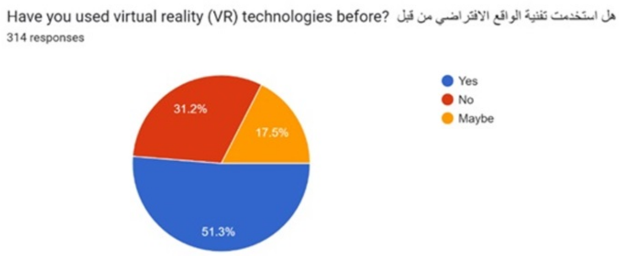

Figure 18. Demography information (Previous using)

6.3.2 Mean (Average) Analysis and Standard Deviation

The mean (average) score for each statement reflects the central tendency of the responses (see eq. 2-21). The mean values in the analysis ranged from 3.65 to 4.03. Notably, all mean values are above the midpoint of the scale (3.0), indicating an overall favorable sentiment among participants. The highest mean value (4.03) was observed for the statement, ”I would recommend the VR lab to other electrical engineering students for their studies,” suggesting a strong inclination among participants to endorse the VR lab to their peers. The lowest mean value (3.65) pertained to the statement, ”The VR lab’s user interface is easy to navigate,” which still indicates a generally positive sentiment, albeit with a slightly lower level of agreement. Standard deviation values were calculated to assess the level of variability or dispersion in the responses for each statement. The standard deviation values ranged from 1.070 to 1.251. These values signify that while there is some variability in the responses, it is within a moderate range. The statement "I can easily switch between different features and tools with-in the VR lab," had the smallest standard deviation (1.070), indicating relatively high consensus among the subjects who took the test. Conversely, the statement with the most diverse responses was "The VR lab can enhance my ability to apply theoretical knowledge to practical." Its standard deviation was 1.251, showing that opinions were far less homogeneous on this question. On average, the mean scores reflect a generally favorable tendency from participants, and some statements were endorsed at particularly high levels. As for the standard deviation values, they suggest that subjects are quite evenly distributed in their evaluations. Table 2 shows the respondents' statistics in terms mean and standard deviation.

7 Conclusion

In this study, the synergy between stitched image rectification and their impact on the creation of VR environments in electrical laboratories using panoramic images have been critically evaluated. The fact that VR has transformative potential and is based on immersion and interactivity has inspired its further study as a mechanism of promoting active learning and bringing students closer to what they study. The utilization of image rectification on top of image stitching processes is the base of the creation of continuous panoramic images. The use of modern algorithms like SIFT have been enabled to effortlessly join panoramas such that the scenes are seamlessly put together to create a realm of immersive virtual worlds. Robust assessments employing metrics like PSNR, SSIM, FID, and others emphasize the crucial need for having visually rich environments which make the users fully inscribe. Integrating the technical part of this feature is the use of Unity Game Engine which allows the users to interact with the elements of the laboratory. Through this method the user becomes fluent in navigating and manipulating objects whilst, at the same time, achieving a better understanding of complex connections which advance users while in the theoretical learning processes. On top of that, immersed VR environments are very much affecting student engagement and comprehension based on the findings of surveys conducted. The plaudits obtained from the public stand for the significance of developing the immersive space by means of the photos' correction. Using concrete examples such as power transfer analysis or control panels of water pumps in irrigation projects, the range of applications of immersive VR situations were demonstrated. These innovative tools are designed to provide students with a real-time experience on complex concepts transforming them into analytical and problem-solving experts even in a virtual setting through collaborative learning. To go even further, more sophisticated immersive VR laboratories are envisioned using projection technologies combined with planetary correction techniques and interactive tools such as Unity. This study not only underscores the transformative potential of VR technology in education but also emphasizes the crucial role of rectifying stitched images in creating immersive environments that enrich learning experiences. In future research VR laboratory's bettering the user interface and interaction design could be further pursued in order to improve usability and involvement of users. However, along with that, teaming up with the scholars and running extensive studies over a long-er period of time will result in a valuable data. In addition to that analyzing the implications of introducing advanced technologies like augmented reality (AR) and artificial intelligence (AI) to VR laboratory will serve much better functionality and personalized learning experiences. Lastly, partnering with educators and practitioners to develop a supplementary lesson plan and cases based on the more difficult topics of electrical engineering would expand the educational benefits of the VR laboratory. These mechanisms for future research are proposed to move the technology forward and make it more relevant and applied for engineering education. The areas of research for the future are aimed at the development of VR technology and engineering education both the scale and the effectiveness. They...aim at VR technology's effectiveness and applicability advancement in the engineering education field. These paths of study are meant to be used in the evolution of VR in engineering education to make it more applicable. These mechanisms for future research are proposed to move the technology forward and make it more relevant and applied for engineering education. These pathways for further re-search seek to move further the efficacy and relevance of VR technology in engineering educational settings.

Table 2. Questionnaire Items Based on TAM Model

No.	Questions	N		Mean	Std. Deviation
		Valid	Missing		
1	Using the VR lab can help me understand complex electrical engineering concepts.	314	0	3.73	1.172
2	The VR lab can enhance my ability to apply theoretical knowledge to practical.	314	0	3.82	1.251
3	The VR lab's simulations are relevant and valuable for my electrical engineering studies.	314	0	3.73	1.171
4	The VR lab improves my overall learning experience in electrical engineering.	314	0	3.83	1.169
5	I believe the VR lab is an effective tool for deepening my understanding of specialized topics within electrical engineering.	314	0	3.92	1.191
6	The VR lab contributes positively to my grasp of real-world applications in electrical engineering.	314	0	3.92	1.125
7	I find the VR lab's content to be directly applicable to my academic goals in electrical engineering.	314	0	3.90	1.165
8	The VR lab's user interface is easy to navigate.	314	0	3.65	1.143
9	I quickly adapted to using the VR lab's controls and interactions.	314	0	3.86	1.197
10	Learning to use the VR lab was straightforward.	314	0	3.82	1.179
11	I feel confident using the VR lab's technology without difficulties.	314	0	3.86	1.151
12	The VR lab's interface is intuitive and user-friendly.	314	0	3.93	1.103
13	Interacting with the VR lab's simulations feels natural and comfortable.	314	0	3.99	1.129
14	I can easily switch between different features and tools within the VR lab.	314	0	3.95	1.070
15	I am likely to allocate additional time to use the VR lab for my electrical engineering studies.	314	0	3.66	1.159
16	The VR lab has the potential to replace traditional lab sessions for certain electrical engineering experiments.	314	0	3.86	1.189
17	I am open to integrating the VR lab into my regular study routine.	314	0	3.86	1.165
18	The VR lab is a valuable resource that complements my other learning materials.	314	0	3.89	1.223
19	I am willing to invest effort in exploring various aspects of the VR lab to maximize its benefits.	314	0	3.93	1.145
20	I would recommend the VR lab to other electrical engineering students for their studies.	314	0	4.03	1.153
21	I can see myself relying on the VR lab for a substantial portion of my electrical engineering coursework.	314	0	3.91	1.206
22	I am confident in my ability to use technology effectively for learning.	314	0	3.82	1.136
23	I have experience using VR technologies for educational purposes.	314	0	3.86	1.198
24	I am comfortable using various digital tools and software.	314	0	3.93	1.135
25	I am familiar with the general principles of virtual reality technology.	314	0	3.86	1.155
26	I consider myself capable of quickly adapting to new technology-driven learning environments.	314	0	3.96	1.181
27	I am enthusiastic about the opportunity to use the VR lab for my electrical engineering studies.	314	0	3.79	1.186
28	I have a positive outlook on how the VR lab can enhance my performance in electrical engineering courses.	314	0	3.87	1.173
29	The VR lab excites me as a tool for expanding my understanding of complex electrical engineering concepts.	314	0	3.88	1.130
30	My overall impression of the VR lab is favorable.	314	0	4.02	1.143

Authors' Contributions

Zainab M. Hussain provided supervision, revision, and editing. Muntasser A. Wahsh provided the idea, technique, software, formal analysis, materials, data collection, and writing-original version preparation. Mays.A.Wahish , revi-sion, and editing.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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