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AMAZE

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MODULE 7

Virtual Reality (VR) and Augmented Reality (AR)

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Authors	**Sergio Vizcaino, Beatriz Gloria BONILLA GARCIA, César Arcadio BONILLA GARCIA**
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1 *Introduction to Virtual Reality (VR) and Augmented Reality (AR)*

Virtual Reality (VR) and Augmented Reality (AR) are innovative technologies that offer distinct approaches to enhance additive manufacturing processes. In the realm of virtual reality, users are transported to entirely digital environments using devices such as VR headsets. This is particularly useful in additive manufacturing, where VR enables the creation of detailed simulations of the entire process, from initial design to the 3D printing phase. Engineers and operators can interact with three-dimensional models, adjust parameters, and conduct virtual tests before implementing processes physically. Furthermore, virtual reality facilitates operator training by providing practical simulations and remote collaboration, allowing dispersed teams to collaborate efficiently in a shared virtual environment.

In contrast, augmented reality adds a digital layer to the physical world, overlaying graphical information or contextual data in real-time. In the context of additive manufacturing, AR stands out by providing visual instructions directly in the workspace during the assembly process of 3D-printed products. Operators can benefit from precise and real-time visual guides, improving accuracy and reducing errors. Additionally, AR is used for real-time monitoring of 3D printers, displaying crucial data about the printing status, temperature, and other key parameters. This direct and contextual information facilitates informed decision-making and contributes to the early detection of potential issues.

The choice between virtual reality and augmented reality in additive manufacturing depends on specific objectives and the nature of the task at hand. While virtual reality offers total immersion in simulated environments, augmented reality enhances the physical environment

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with relevant digital information. The combination of both technologies, known as mixed reality, is also being explored to harness the best of both worlds. Collectively, these technologies are transforming how challenges are addressed and processes are optimized in additive manufacturing.

1.1. Virtual Reality (VR)

Virtual Reality (VR) plays a crucial role in additive manufacturing by providing an immersive environment that significantly enhances design, simulation, and operator training processes. Firstly, in the realm of design, VR enables engineers to visualize and manipulate 3D models in a three-dimensional space, facilitating the creation and optimization of designs for 3D printing. This virtual approach reduces the need for physical prototypes, speeding up the development cycle and saving costs.

Fig.1. Using Virtual Reality

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Secondly, VR is used for process simulation in additive manufacturing. Users can virtually experience each step of the process, from setting up the 3D printer to optimizing parameters, before carrying out the physical print. This helps identify potential issues and adjust variables efficiently, improving operational effectiveness and reducing material waste.

Thirdly, VR is employed in operator training. New operators can familiarize themselves with handling 3D printers and learn to troubleshoot potential problems in a virtual environment, expediting the training process and ensuring a consistent level of skills across the team.

In summary, virtual reality in additive manufacturing not only optimizes design and simulation but also transforms operator training by providing immersive learning experiences. These combined VR applications contribute to increased efficiency and accuracy in additive manufacturing, driving the adoption of advanced technologies in the manufacturing industry.

1.2. Augmented Reality (AR)

Augmented Reality (AR) plays a crucial role in the transformation of additive manufacturing, providing significant benefits in terms of efficiency and precision. Firstly, AR is used to enhance the assembly process of 3D-printed products by overlaying visual instructions directly in the operator's field of view. This not only simplifies and speeds up the assembly process but also reduces the possibility of errors by providing real-time visual guidance. AR thus contributes to the improvement of quality and productivity in the production chain.

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Fig.2. Example of Augmented Reality

Secondly, AR is employed for real-time monitoring of 3D printers. Operators can visualize crucial data, such as print progress, temperature, and other key parameters, directly on the printer. This facilitates early detection of potential issues, allowing for quick interventions and minimizing the risk of errors in the additive manufacturing process. Additionally, AR can provide information about the printer's status in an intuitive and accessible manner, enhancing decision-making.

Thirdly, AR is integrated into operator training in additive manufacturing. It enables the creation of immersive and practical training experiences, where operators can learn to interact with 3D printers and perform specific tasks in a virtual environment. This not only accelerates the training process but also improves knowledge retention by providing a more visual and hands-on learning experience.

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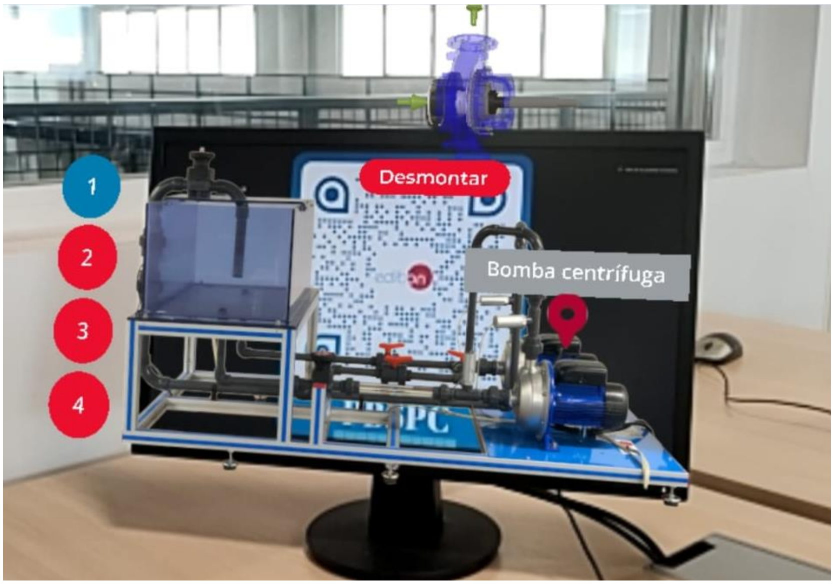

Fig.3. Example of Augmented Reality

In summary, augmented reality in additive manufacturing not only optimizes assembly and process monitoring but also revolutionizes operator training by providing more immersive learning experiences. These advancements contribute to more efficient and precise production in additive manufacturing, driving the adoption of cutting-edge technologies in the manufacturing industry.

2 Contextualization of the Importance of VR and AR in Additive Manufacturing

The integration of Virtual Reality (VR) and Augmented Reality (AR) in additive manufacturing represents a significant advancement that fundamentally transforms the way the manufacturing process is conceptualized, developed, and executed. This convergence of innovative technologies introduces a series of key benefits that positively impact the

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efficiency, precision, and flexibility of additive manufacturing. The contextualization of its importance can be understood through the following points:

a. Improvement in Visualization and Design: The combination of virtual reality (VR) and augmented reality (AR) has brought notable improvements in visualization and design across various industries, particularly standing out in the realm of manufacturing. Firstly, virtual reality allows designers to immerse themselves in three-dimensional environments, facilitating a deeper understanding of models and prototypes. This immersion enhances spatial perception and the detection of potential design issues, enabling adjustments and optimizations before production.

Fig.4. Concept of Augmented Reality

On the other hand, augmented reality offers an overlay of digital information in the real world, proving invaluable for visualization during the design phase. This technology enables engineers to view 3D models directly in the physical environment, facilitating the evaluation

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of sizes, proportions, and spatial relationships. Additionally, AR can be used to project real-time data about the production status, such as temperatures, speeds, and other parameters, contributing to more informed decision-making.

Together, VR and AR provide powerful tools to enhance visualization and design in manufacturing. From immersive prototyping to overlaying relevant information during production, these technologies are transforming how professionals interact with designs and optimize manufacturing processes. This innovative approach not only drives efficiency but also promotes more precise decision-making and continuous improvement in product quality.

b. Iterative Design and Rapid Prototyping: Virtual reality allows designers to create and modify models in an immersive three-dimensional environment. This facilitates rapid design iteration and the creation of virtual prototypes before physical production. Designers can visualize and evaluate the design from different perspectives to make precise adjustments.

Iterative design and rapid prototyping are key elements in the additive manufacturing process. Additive manufacturing, including technologies like 3D printing, enables the creation of three-dimensional objects layer by layer from digital data. Here is a description of how iterative design and rapid prototyping are integrated into the context of additive manufacturing:

c. Rapid Iteration: Additive manufacturing allows for rapid iterations in design. Designers can make changes to the digital model and then print an updated prototype in a short amount of time.

d. Design Optimization: The ability to manufacture objects layer by layer facilitates design optimization. Designers can adjust geometry to improve structural efficiency, reduce weight, or meet other specific requirements.

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e. Function-Based Design: Designers can focus on the performance and function of the object, as additive manufacturing allows the creation of structures and geometries that would be difficult or impossible to achieve with traditional manufacturing methods.

f. Fast Feedback: By easily and relatively inexpensively printing prototypes, quick feedback on designs is obtained. This facilitates the identification of issues and the implementation of improvements.

g. Cost and Time Reduction: Compared to traditional prototyping methods, additive manufacturing can significantly reduce costs and times associated with prototype creation. Determining the exact percentage of cost and time reduction when using virtual reality (VR) and augmented reality (AR) in additive manufacturing may depend on various factors, including the type of application, the complexity of the manufacturing process, and the effectiveness of the implementation of these technologies. However, in general, significant improvements in terms of efficiency and productivity can be expected. Here are some general estimates based on common use cases:

h. Design and Prototyping: The use of VR for design and prototype visualization can reduce development time and design iterations. Reductions of up to 30-40% in development time have been reported in some industries.

i. Collaboration and Communication: Real-time collaboration facilitated by VR and AR can decrease design review and approval times, contributing to cost reductions associated with decision-making delays.

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j. Process Simulation and Error Detection: Process simulation in VR can help identify and correct potential design errors before production, resulting in significant savings by avoiding defects and rework. Cost reductions in this area can exceed 20-30%.

k. Assembly Instructions and Training: The use of AR to provide assembly instructions and training can accelerate operators' learning curve and reduce the time needed to perform specific tasks. This can lead to cost reductions related to training and operational efficiency.

l. Inspection and Maintenance: AR used in virtual inspections can improve efficiency in the quality and maintenance process, reducing the time needed to assess and address issues. This can translate into time and maintenance cost savings.

It is important to note that these percentages are general estimates, and specific results may vary depending on the implementation and context. The successful adoption of VR and AR in additive manufacturing can not only reduce production costs and times but also improve product quality and customer satisfaction.

m. Design Validation: 3D-printed prototypes allow designers and engineers to validate the design before moving to large-scale production. Aspects such as shape, functionality, and ergonomics can be evaluated.

Design validation through the combination of virtual reality (VR) and augmented reality (AR) revolutionizes the product development process by giving designers and engineering teams the ability to immerse themselves in immersive virtual environments. In VR environments, three-dimensional models come to life, allowing for a thorough evaluation of every aspect of the design. This ability to interact and visualize in real-time facilitates the early identification

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of potential issues and the making of instant adjustments, drastically reducing the time needed for iterations and perfecting the design. Additionally, augmented reality adds a practical component to the process by overlaying virtual models on the real world, providing a tangible perspective of the design and allowing the assessment of key factors such as size and integration into the real environment.

The integration of VR and AR in design validation not only speeds up iterations but also fosters more efficient collaboration among multidisciplinary teams. The ability to collaborate in real-time in virtual environments enhances communication between designers, engineers, and other stakeholders, allowing for immediate feedback. This approach not only reduces the likelihood of design errors but also contributes to the overall efficiency of the product development process, enabling the creation of more innovative and competitive products in the market.

n. Error Detection: The rapid prototyping process facilitates early detection of design errors. By printing prototypes and evaluating their physical performance, problems can be identified and corrected before investing in expensive production tools.

o. Customization and Parametric Design: Additive manufacturing allows for the creation of customized prototypes and exploration of parametric designs, where model parameters can be easily adjusted to evaluate different configurations.

In summary, the combination of iterative design and rapid prototyping in additive manufacturing provides designers and engineers with a powerful tool to innovate, experiment, and refine their designs efficiently before scaling up to large-scale production. This approach helps accelerate the product development cycle and improve the quality and efficiency of the design process.

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3 *Interactivity and Immersive Experience*

Virtual reality environments offer an interactive and more immersive experience. Designers can manipulate 3D objects more naturally, enhancing spatial understanding and decision-making during the design process.

Fig.5. Example

Interactivity and immersive experience are fundamental elements in virtual reality (VR) and augmented reality (AR), transforming the way we interact with digital information and virtual objects. Here are some key aspects of how interactivity and immersive experience are applied in these environments:

Real-Time Interaction:

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- Direct Manipulation: The ability to interact directly with virtual objects using gestures, touch controls, or specialized input devices.
- Motion Recognition: VR and AR systems can track and recognize user movements to provide a more natural interaction experience.

Navigation and Exploration:
- Three-Dimensional Exploration: The ability to explore virtual environments or 3D information, allowing for a more immersive and detailed experience.
- Gesture-Based Navigation: Using gestures to navigate virtual environments or access information in augmented reality applications.

Simulation and Visualization:
- Interactive Simulations: Creating interactive simulations in VR for training, education, or prototyping.
- 3D Data Visualization: The ability to visualize complex data in three dimensions, facilitating understanding and analysis.

Remote Collaboration:
- Virtual Meetings: Facilitating meetings and collaboration among users located in different places through shared virtual reality environments.
- Project Collaboration: Collaborating in real-time on projects, designs, or presentations using VR or AR devices.

Training and Simulation:
- Immersive Training: Using virtual reality to train individuals in simulated environments, such as emergency situations or workplace practices.

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- Simulation of Complex Scenarios: Creating simulation environments that mimic realistic situations for training and skill development.

Interactive Education:

- Interactive Lessons: Developing educational content that allows students to interact with 3D models, explore concepts in three dimensions, and actively participate in learning.
- Virtual Experiments: Conducting virtual experiments or visualizing scientific phenomena interactively.

Personalization and User Experience:

- Environment Customization: Allowing users to customize their virtual environment, from appearance to the arrangement of elements.
- Intuitive User Interface: Designing intuitive and user-friendly interfaces that enhance the user experience in VR and AR environments.

Gamification:

- Game Elements: Integrating game elements and gamification to make experiences more engaging and motivating.
- Interactive Stories: Developing interactive narratives that engage the user and provide an immersive experience.

Interactivity and immersive experience are essential to fully harness the potential of virtual and augmented reality. These technologies are transforming various fields, from education and entertainment to industry and medicine, providing new ways to interact with the digital and physical world.

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4 Visualization in Detail

VR allows for detailed visualization of 3D models, even at a much larger scale than would be possible on a conventional screen. This is crucial for assessing the complexity and accuracy of models before production. Detailed visualization in virtual reality (VR) and augmented reality (AR) is essential for providing immersive and understandable experiences. Here are some key aspects of how detailed visualization is achieved in these environments:

Virtual Reality (VR):

Resolution and High-Quality Graphics:

- Use of high-resolution displays to provide sharp and detailed images.
- High-quality graphics to represent textures and details realistically.
- Motion and Position Tracking:

Precise tracking systems that allow exact correlation between user movements and real-time view in the virtual environment.

Position tracking technologies to enable movement in virtual space and detailed inspection. Realistic Lighting: modelling of realistic lighting to simulate shadows, reflections, and light effects contributing to detail perception.

Interactivity and Manipulation:

- Interactive tools that allow users to manipulate virtual objects and explore specific details through gestures and controls.

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- Detailed animations to represent processes or events realistically.
- Detailed simulations of phenomena, allowing real-time visualization.
- Complex 3D Environments:

Detailed representation of 3D environments with complex geometry and realistic textures. Detailed scenarios including landscapes, buildings, and objects with high fidelity.

Remote Collaboration:

VR platforms that enable real-time collaboration, facilitating visualization and discussion of details among users in different locations.

Augmented Reality (AR):

Anchoring in the Real World:

- Precise overlay of virtual elements in the user's physical environment.
- Correct alignment of virtual objects with their real context.
- Markers and Object Recognition:

Use of visual markers or object recognition to place virtual information contextually and in detail.

Integration of detailed information about products, buildings, or objects through visual recognition.

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Visualization of Contextual Data: presentation of contextual and detailed data about objects in real time, such as technical information, specifications, or related data.

Navigation Assistance: display of navigation cues in the user's field of vision to aid orientation and navigation.

Detailed information about points of interest and destinations in the environment.
Work Instructions and Maintenance:

Providing detailed and animated work or maintenance instructions on physical objects through AR.

Visualization of step-by-step guides for specific tasks.

5 Remote Collaboration, Information Sharing and Collaborative Design

The simulation of processes and environments through virtual reality (VR) and augmented reality (AR) technologies has transformed the way various industries visualize, understand, and make crucial decisions. Firstly, these technologies enable the optimization of industrial processes by allowing the virtual testing of different scenarios, identifying potential bottlenecks, or inefficiencies. This is particularly valuable in sectors such as manufacturing, where assembly lines and production flows can be simulated to improve operational efficiency.

Secondly, virtual simulations offer a safe and realistic environment for training, allowing professionals to practice and refine their skills in fields such as medicine, aviation, and

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manufacturing. Augmented reality, by overlaying digital information onto real-world scenarios, enhances training by providing context-specific guidance for each situation. Furthermore, these technologies are crucial for assessing the environmental impact of projects, visualizing how they could affect the surrounding environment, and supporting informed decisions in areas such as urban planning and sustainable architecture.

Thirdly, simulation in VR and AR is used to plan and rehearse responses to emergencies, from natural disasters to industrial accidents. This allows organizations and response teams to anticipate various situations, improving coordination and preparedness for real crises. Additionally, these technologies contribute to simulating the entire lifecycle of a product, from design and manufacturing to maintenance and final disposal, providing a comprehensive and sustainable view.

In conclusion, simulation in VR and AR not only provides valuable information for decision-making but also enhances operational efficiency, safety, and sustainability across a variety of sectors. From urban planning to workplace training, these technologies are revolutionizing how businesses and professionals approach everyday challenges, fostering more informed and collaborative decision-making.

6 Simulation of Industrial Processes

In the realm of Virtual Reality (VR), diverse applications revolutionize manufacturing, training, and collaborative design. Virtual Manufacturing Environments empower industries by creating digital replicas of manufacturing processes, allowing for comprehensive training and optimization before actual implementation. Assembly Simulation takes this a step further, enabling the visualization and virtual practice of complex assemblies, thereby enhancing operational efficiency and precision in real-world scenarios.

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Fig.6. Virtual Reality improves the ability to manipulate without using real items

Training and Education enter a new era with VR-based Training Simulators, offering immersive experiences for operators, pilots, and medical professionals. These simulators provide realistic scenarios, allowing professionals to hone their skills in handling complex or emergency situations within a safe and controlled virtual environment. The three-dimensional data visualization capabilities of VR extend to Data Analysis, where complex data sets are represented spatially, fostering a deeper understanding and facilitating analysis and decision-making processes.

In the planning and design domain, VR transforms the way spaces are conceptualized. Virtual Tours enable architects and planners to navigate and assess architectural spaces before construction, while Interior Visualization provides a realistic simulation of how building interiors or facilities will look. Project Collaboration experiences a paradigm shift with VR, facilitating Virtual Design Meetings in shared environments and enabling real-time collaborative editing of 3D models and simulations. This convergence of VR technologies

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across industries underscores their transformative impact on training, design, and collaborative processes.

The section discusses the applications of Augmented Reality (AR) across various domains, emphasizing its role in enhancing maintenance processes. In maintenance, AR proves valuable by overlaying maintenance instructions and visual guides directly onto equipment and machinery, simplifying the maintenance process. It also aids in problem detection by using AR to highlight issues or areas of interest in physical environments, contributing to swift issue resolution.

The text further delves into the visualization of contextual data using AR. It describes the overlay of contextual information on physical objects, offering insights into the integration of AR technologies to display real-time data on physical devices. AR is also employed for navigation and orientation, providing cues, routes, and virtual signs in the real world to facilitate navigation and decision-making, showcasing its practicality in diverse scenarios.

Moreover, the narrative introduces Augmented Prototyping and Augmented Parametric Design as applications of AR in rapid design and prototyping. These processes involve creating virtual prototypes on physical objects and adjusting designs in real-time through AR applications, demonstrating the efficiency and flexibility AR brings to design iterations. Lastly, the text touches upon the role of AR in remote collaboration and assistance, allowing experts to collaborate remotely and guide workers through complex tasks using visual overlays.

In a related context, the passage briefly mentions the advantages of simulation in Virtual Reality (VR) and AR across sectors, emphasizing their ongoing evolution to offer more immersive and functional experiences in complex processes and environments. It underscores

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the transformative impact of these technologies on efficiency, safety, and informed decision-making.

In a separate but related discussion, the use of Virtual Reality (VR) in training and orientation for designers and operators in handling additive manufacturing equipment is highlighted. Virtual simulators provide a safe and effective platform for practice before interacting with real equipment, contributing to improved skills and operational readiness. Additionally, immersive visualization in VR is credited with providing a deeper understanding of designs and manufacturing processes, thereby enhancing decision-making and reducing errors in additive manufacturing. The text underscores how VR has fundamentally changed professionals' approaches to creating and producing three-dimensional objects, offering tangible benefits in terms of efficiency, precision, and collaboration.

7 Immersion

Virtual Reality (VR) facilitates an immersive environment that allows designers and manufacturers to visualize 3D models in three dimensions before printing. This not only accelerates the design process but also enhances decision-making by providing a deeper understanding of the geometry and structure of the object to be printed.
Real-Time Process Simulation:

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Fig.8. Example of remote collaboration

VR enables real-time simulation of additive manufacturing processes. By allowing operators to interact with virtual environments, potential issues can be identified, and parameters can be optimized before physical printing takes place. This reduces costs associated with errors and material waste.

Operation Assistance:

Augmented Reality (AR) provides assistance in operating 3D printers by offering real-time information about the machine's status, assembly instructions, and other relevant data. This improves operational efficiency and reduces downtime.

Remote Collaboration and Access to Experts:

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The integration of VR and AR facilitates real-time remote collaboration. Experts can virtually assist in problem-solving, process optimization, and decision-making, regardless of their geographical location.

Value Chain Optimization:

The application of these technologies in the additive manufacturing value chain optimizes the flow from design conception to production. VR and AR become valuable tools that accelerate the product life cycle and improve overall efficiency.

Facilitation of Education and Training:
VR and AR offer virtual training environments, allowing manufacturing professionals to acquire skills and practical experience safely and effectively, contributing to the training of a highly skilled workforce.

The contextualization of the importance of VR and AR in additive manufacturing lies in their ability to optimize processes, improve decision-making, reduce costs, and open new possibilities for innovation in the realm of three-dimensional production. These technologies not only enhance operational efficiency but also drive the evolution of additive manufacturing toward a more advanced and adaptive future.

Augmented Reality

Augmented Reality (AR) has emerged as a key technology in additive manufacturing, offering advanced capabilities that enhance efficiency, precision, and interaction throughout the three-dimensional printing process. Here are the key aspects of applying AR in additive manufacturing:

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Assistance in 3D Printer Operation:

Augmented Reality (AR) provides real-time information about the status of 3D printers, allowing operators to effectively monitor machine operation. Data such as temperature, printing speed, and material level is displayed directly on the printer, improving supervision and facilitating decision-making.

Contextual Data Visualization:

AR offers contextual visualization of data related to additive manufacturing. Users can see relevant information, such as assembly instructions, printing parameters, and alerts, overlaid in the physical environment, simplifying understanding and task execution.

Real-time Inspection and Quality Control:

By overlaying visual information, AR facilitates real-time inspection and quality control during the additive manufacturing process. Operators can identify and correct potential defects immediately, reducing the likelihood of producing faulty parts.

Assembly and Maintenance Guides:

AR is used to provide step-by-step visual guides during the assembly and maintenance of 3D printers. This enhances efficiency and reduces errors by offering clear visual instructions directly on the parts to be assembled or maintained.

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Fig.9. Augmented Reality can allow to manipulate and observe mechanisms easily

Remote Collaboration and Technical Support:

AR enables remote collaboration by superimposing the image of experts in real-time on the operator's field of vision. This facilitates problem resolution and the provision of technical support, even when experts are in different geographic locations.

Visualization of Results Before Printing:

AR enables the visualization of virtual results before carrying out physical printing. Designers and operators can see how the final product will look in its real environment, facilitating decision-making before initiating the manufacturing process.

The effective application of AR in additive manufacturing improves operational accuracy, product quality, and collaboration among teams. From real-time assistance to visual inspection and assembly guidance, AR enhances the three-dimensional printing experience, supporting the continuous evolution of additive manufacturing.

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8 Mixed Reality: Discovering the Future of Immersive Technology

Mixed reality is an innovative technology that combines the physical and digital worlds, providing users with a new level of interaction and immersion.

It combines elements of virtual reality (VR) and augmented reality (AR) to create a seamless environment where users can interact with real and virtual objects in real-time. The virtuality continuum represents the spectrum between the entirely physical and entirely digital, with mixed reality positioned somewhere in between, allowing the coexistence of these two worlds.

Fig.10. Example of Mixed Reality

Advancements in computer vision, graphic processing, visualization technologies, input systems, and cloud computing have made mixed reality more accessible and versatile. This has

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led to the development of various mixed reality devices designed to meet different needs and experiences. The technology and design of these devices have evolved over time with the goal of providing a smooth and intuitive user experience across a wide range of applications.

Mixed reality has diverse applications, including entertainment, education, training, and business. From video games to product design and simulations, mixed reality allows users to immerse themselves in complex scenarios and explore new possibilities in a natural and engaging way. As technology continues to advance, the potential for real-world implementation and the development of mixed reality experiences increases, with developers constantly exploring innovative ways to merge the digital and physical worlds.

Key Points:
- Mixed reality merges the physical and digital worlds, providing users with enhanced interaction and immersion.
- Technological advancements have resulted in various mixed reality devices and applications.
- Mixed reality has potential for diverse real-world implementations, including entertainment, education, and business.

Mixed Reality Devices

In the world of mixed reality (MR), various devices allow users to experience a combination of real and virtual environments. This section covers some of the standout MR devices, including headsets, wearables, HMDs, Hololens, and consoles.

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Headsets

Headsets play a significant role in the mixed reality experience, enabling users to visualize the virtual environment merged with their real surroundings. A popular option is the Windows Mixed Reality headset, compatible with Windows 10 PCs. These devices consist of two main components: the headset itself and motion controllers for interaction with the virtual world. Many headsets also require a USB cable to connect to a PC.

Fig.11. Example of Headset

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Wearables

Wearables, such as smartphones and tablets, can also provide mixed reality experiences through the use of specialized applications and sensors. These devices often use cameras for tracking and projecting virtual objects onto the real world. While not as immersive as headsets, portable mixed reality devices offer greater flexibility and accessibility, as many users already own smartphones that can support these applications.

Fig.12. Example of Wearables

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HMD (Head Mounted Display)

A head-mounted display (HMD) is a type of wearable device that projects images and information into the user's field of vision. HMDs are commonly used in mixed reality experiences, with devices like Microsoft HoloLens providing both immersive visualizations and interactions with virtual content. HMDs often include integrated motion tracking and gesture recognition for more natural navigation and control within the mixed reality environment.

Fig.13. Example of HMD

Consoles

Mixed reality experiences can also be enjoyed through gaming consoles, such as Xbox or PlayStation systems. These consoles can be paired with various MR-compatible headsets and controllers to provide an immersive gaming experience. While not as common as PC-based mixed reality, console-compatible MR is growing in popularity with the increasing prominence of virtual and augmented reality technologies.

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Fig.14. Example of interaction with mixed reality

By understanding the different types of mixed reality devices available and their unique features, users can choose the best solution to meet their needs. From headsets and wearables to HMDs, and consoles, there are many options to explore and enjoy mixed reality environments.

9 Programming and Software in Virtual Reality and Augmented Reality

Programming and software are essential elements that drive the creation of immersive experiences in the field of Virtual Reality (VR) and Augmented Reality (AR). Both technologies, although distinct in their approaches, share the need for specific tools and programming skills to carry out successful projects.

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Virtual Reality (VR):

In the development of Virtual Reality applications, programmers rely on integrated development environments (IDEs) such as Unity or Unreal Engine. These platforms offer a robust set of visual tools and predefined components that simplify the creation of immersive three-dimensional environments. Commonly used programming languages include C# for Unity and C++ for Unreal Engine. Programming for VR involves managing interactivity, user navigation, and application logic, using concepts such as VR scripting to control the behavior of virtual objects. Additionally, VR programming often includes performance optimization to ensure a smooth and latency-free experience.

In addition to the programming component, software for VR encompasses design and 3D modeling tools. Software such as Blender or Autodesk Maya allows developers to create realistic three-dimensional models that will be an integral part of the virtual experience. Similarly, the VR development process involves audio integration and the implementation of intuitive user interfaces to enhance user immersion.

Augmented Reality (AR):

In the case of Augmented Reality, programming focuses on overlaying digital information onto the physical environment. Frameworks such as ARKit (for iOS devices) and ARCore (for Android devices) provide tools and APIs that facilitate the integration of virtual elements into the real world. Developers use languages such as Swift for iOS or Java/Kotlin for Android, adapting to specific platforms. AR programming involves a precise understanding of the device's real-time position and orientation, enabling the accurate placement of virtual objects in the physical environment.

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AR software also includes specific design tools that allow the creation and optimization of digital content to overlay onto the real world. AR design is a meticulous process that requires special considerations for scale, lighting, and interaction with real-world objects. The use of 3D modelling software, along with rendering engines, contributes to the creation of visually appealing and consistent AR experiences.

Collaboration and Agile Development:

In addition to programming and design, the VR and AR development process involves collaboration and project management. Source code management platforms, such as GitHub, are essential for facilitating collaboration among team members and enabling continuous integration in the development of these immersive applications. Agile software development methodologies align well with virtual and augmented reality projects, allowing for rapid iteration and effective response to changes and feedback during development.

Conclusion:

In summary, programming and software play crucial roles in creating engaging experiences in Virtual Reality and Augmented Reality. From choosing development environments to implementing realistic 3D designs and efficiently managing source code, a comprehensive approach ensures success in materializing projects that transform the way we interact with the digital and physical reality.

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10. Summary and comparison between technologies

Features	Augmented Reality	Virtual Reality
Definition	Overlays digital and visual information onto the real world.	Creates a completely new and artificial virtual environment.
Device used	Mainly mobile devices, screens, cameras, making it more accessible. AR can also be experienced through AR glasses.	Always requires devices such as VR glasses, VR headsets, motion tracking devices.
Interaction	Interaction with both the real world and virtual objects.	Interaction only with virtual objects in a virtual world.
Cost	Less expensive technology. Affordable solutions are available for any company and user.	Requires a much higher investment.
Applications	Advertising, marketing, gaming, education, navigation, medicine, construction, architecture, retail, industry, tourism, sports, events, culture, e-commerce, and more.	Video games, training simulation, entertainment experiences, design and prototyping, psychotherapy, occupational therapy, among others.
Visualization and Sharing	Allows sharing the same experience with other users in the same physical space.	Does not allow sharing the same experience with other users in the same physical space.

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Comfort	Can be worn for longer periods without causing visual fatigue or dizziness.	May cause visual fatigue or dizziness after short periods of use.
Limitations	Requires a well-lit environment to function properly.	Requires a spacious and well-lit space to avoid collisions with physical objects.
Level of immersion	Offers a partial level of immersion, meaning the experience feels like virtual objects are overlaid onto the real world.	Offers a total level of immersion, meaning the experience feels like the user is inside a completely new virtual world.
Learning	May be more intuitive for users, as it is based on real-world objects and overlays relevant information.	May have a steeper learning curve, as users need to learn to navigate and manipulate objects in a new virtual environment.
Accessibility	Much more accessible since nowadays everyone has a mobile phone to consume an AR experience.	Less accessible for all users as different specific devices are required.

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