Enabling Industry 4.0 Skills in Textile SMEs
Augmented Reality & Virtual prototyping

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1. The Principles of Augmented Reality (AR)

1.1. Introduction

In the age of advanced technology, our interaction with the digital environment has evolved significantly, transforming the way we perceive and engage with the information and objects around us. Technologies such as Augmented Reality (AR), Virtual Reality (VR) and Extended Reality (XR) have revolutionized various fields, from education and entertainment to health and business. These concepts, although distinct in their applications, fit into a common landscape of immersive experiences, giving us unique opportunities to explore and interact with the world around us.

Augmented Reality (AR) refers to the integration of digital content into the real world. This allows users to see additional information, such as images, texts or animations, superimposed on the environment. For example, AR applications can be used in tourism, to provide information about destinations visited, or in retail to allow customers to visualize how a product would look in their own home. A popular example is the IKEA Place app, which allows users to virtually place furniture in their rooms. AR can improve the user's perception and can facilitate a deeper interaction with the available information.

In the literature we find several definitions of Augmented Reality (AR) such as:

- "Augmented reality is a technology that combines digital data with real data, helping users visualize additional information based on the surrounding context." (Caudell, T. & Mizell, D. (1992). "Augmented Reality: An Emerging Technology for Human-Computer Interaction");
- "Augmented reality is a technology that merges the real world with the virtual world, aiming to create a fusion of human perception with digital information" (Milgram, P., & Kishino, F. (1994). "A Taxonomy of Mixed Reality Visual Displays.");
- "Augmented reality is a technology that allows virtual elements to be superimposed on the real world, in real time, in order to improve the user experience." (Azuma, R. (1997). "A Survey of Augmented Reality");
- "AR is a form of technology that augments human perception of reality by integrating digital information into physical environments."(Reitze, M. (2013). "Augmented Reality: Applications and Future Trends");

These definitions reflect various perspectives on augmented reality and how it interacts with the environment. In summary AR is a technology that overlays digital information (images, texts, sounds) on top of the real world, thus improving the user's perception of the environment.

On the other hand, **Virtual Reality (VR)** creates a completely simulated environment where users can experience another reality. By using VR headsets, consumers are transported into a virtual space where they can interact with digital objects and environments. This technology is commonly used in video games, but also in professional training simulations, such as those for pilots or surgeons. The immersive experience offered by VR allows users to feel an integral part of the environment, induced by the realistic sensations and scenarios created by the software.

In terms of **Extended Reality (XR),** this term serves as an umbrella that encompasses AR, VR, and Mixed Reality (MR). XR includes any form of interaction that combines digital and physical

elements, giving users the flexibility to experience various levels of reality. This can range from education applications that use VR for simulations, to collaboration solutions that use AR for virtual meetings. XR is showing promise in various industries, facilitating collaboration and interaction in a way that was not possible before.

Each of these technologies comes with its own advantages and challenges. AR is accessible because it works on most mobile devices, but it can have performance and connectivity limitations. VR provides an immersive experience but requires expensive equipment and can cause discomfort to the user. In contrast, XR, while versatile, faces complex development and standardization challenges.

	AR	**VR**	**XR**
	Augmented Reality	**Virtual Reality**	**Extended Reality**
Definition	AR combines digital elements with the real world through devices such as smartphones, tablets or AR glasses. Users can see additional information or images superimposed on reality.	VR is a fully digital simulation of an environment that the user can interact with through various devices, such as VR headsets, to experience an alternate reality. Users are fully immersed in a virtual environment that can induce sensations similar to those in the real world. (Jaron Lanier, "Dancing in the Mind Field") * The VR experience involves the use of headsets, controllers and other immersive devices.	XR is an umbrella term that includes all forms of immersive technologies, including AR, VR and Mixed Reality (MR). XR refers to experiences that combine elements of multiple realities, whether virtual or augmented. (Paul Milgram and Fumio Kishino - "A Taxonomy of Mixed Reality Visual Displays")
Interaction	Interaction with digital elements integrated into the real world.	Interaction in a completely virtual environment, disconnected from reality.	Flexibility in interactions, combining AR and VR.
Advantages	Improves user experience by adding useful information. Accessibility through mobile devices, without advanced technical requirements. Possibility to integrate interactive learning in various contexts.	Total immersion in virtual experiences, offering realistic sensations. Training and education opportunities without physical risk. Ability to explore dangerous or inaccessible environments.	Versatility through the integration of various technologies. Ability to customize experiences for users. Promotes collaboration and interaction in a digital environment.
Challenges	Hardware limitations, which may restrict the quality of experience. The need to have an Internet connection for some applications. Data privacy and security challenges.	High cost of the VR equipment (headset and accessories). Potential to cause discomfort or dizziness to users due to simulated travel. The need to develop quality content to attract users.	The complexity of developing applications that integrate multiple technologies. The need to standardize protocols for interoperability. Challenges related to the consumption of technical and financial resources.

By using these technologies, users can experience a unique fusion of physical and digital reality, improving the way we learn, work and play. The continued development and implementation of these technologies will have a significant impact on the future of human interactions with technology. Each technology has its own applications, advantages and challenges. However, their shared potential to improve user experiences continues to grow, with applications in fields ranging from education and training to entertainment and commerce.

1.2. Principles of Augmented Reality (AR)

Augmented reality (AR) is an emerging technology that combines digital elements with the physical environment, providing users with an integrated experience. The basic principle of AR focuses on creating meaningful interactions between the user and the virtual content, ensuring that it enhances the perception and understanding of the environment.

Contextual Perception is the key to AR. This technology uses the ability to recognize and understand the surrounding context, integrating digital information in a relevant way. This means that AR continuously analyses data from the environment and adapts to provide useful and accurate information to users.

Interactivity is another essential aspect. Users must be able to connect with virtual objects in a natural and understandable way. This can include simple gestures, voice commands or different methods of interaction, all aimed at creating a personalized and pleasant experience.

AR also aims to provide an **immersive experience**. Users need to feel like an integral part of an enhanced environment, which emphasizes the importance of quality design. A well-crafted interface can make the difference between a mediocre experience and an engaging one.

Another crucial principle **is reactivity and adaptability**. AR content should be able to respond quickly to changes in the environment as well as the user's actions. This responsiveness ensures a fluid interaction, adjusting information in real time to meet the user's needs.

Finally, **information integration** is an essential component of augmented reality. AR should facilitate quick access to the necessary information, thus improving the decision-making process. This involves effectively integrating data from various sources, presenting it in a way that is easy to understand and use.

In conclusion, Augmented Reality is not only a cutting-edge technology, but also a way to improve our everyday experiences by connecting us better with the information around us.

2. Basics of Augmented Reality

2.1. Types of augmented reality

Augmented reality terms and their definitions are useful for understanding AR technology: (Source: Augmented Reality Glossary - AREA (thearea.org))

• **Augmented Reality SDK** - The AR Software Development Kit (SDK) is an all-inclusive software package for creating AR applications. AR SDK includes: 2D and 3D tracking technology, image recognition and tracking, geo-location capabilities, support for cloud storage of objects, support for the Unity game engine, SLAM support, support for wearables and APIs for different computer languages.

• **Field of View** - the size of the augmented reality image when viewed through a display device.

• **Gesture interaction** is a way for users to control and interact with AR-assisted applications. Gestures include all the movements the user can make with their hands, head, and other body parts.

• **Head-Worn Displays** are a common display technology for augmented reality, encompassing everything from lightweight smart glasses to goggles and more elaborate projection displays.

• **Heads-up Display** is a display technology in which relevant information is presented to the user, superimposed on his field of view on a transparent surface, in a user-centric manner.

• **Head Tracking** - a sensor technology that monitors the positioning and orientation of the head.

• **Hotspots** - touchable points in the AR experience that reveal more content or options.

• **Mixed Reality** is a form of AR where digital overlays are blended into the environment and have a spatial relationship with surrounding objects. While the user moves, the overlays stays in the same position, attached to the real environment. Virtual and real objects are potentially indistinguishable.

• **Multimodal interaction** refers to solutions that allow the user to interact with the solutions in multiple ways, which may include speech, touch, vision, and gestures.

• **Marker less AR** - technique that allows the use of any part of the physical environment as a basis for placing superimposed virtual objects.

• **Markup** is the method of creating a composite scene using increments, triggers, or other information.

• **Object Target** objects can be used as targets to trigger the AR experience on camera view recognition.

• **Object Recognition and Tracking** - feature that allows recognition and tracking of arbitrary objects for augmented reality experiences.

• **Optical character recognition** - electronic conversion of images of handwritten or printed texts into automatically coded text.

• **Rendering Engine** is a software module that creates the increments based on the model processed by the tracking module.

• **Recognition** describes the process of finding an image or object in the camera's viewfinder as a starting point for real-time object tracking.

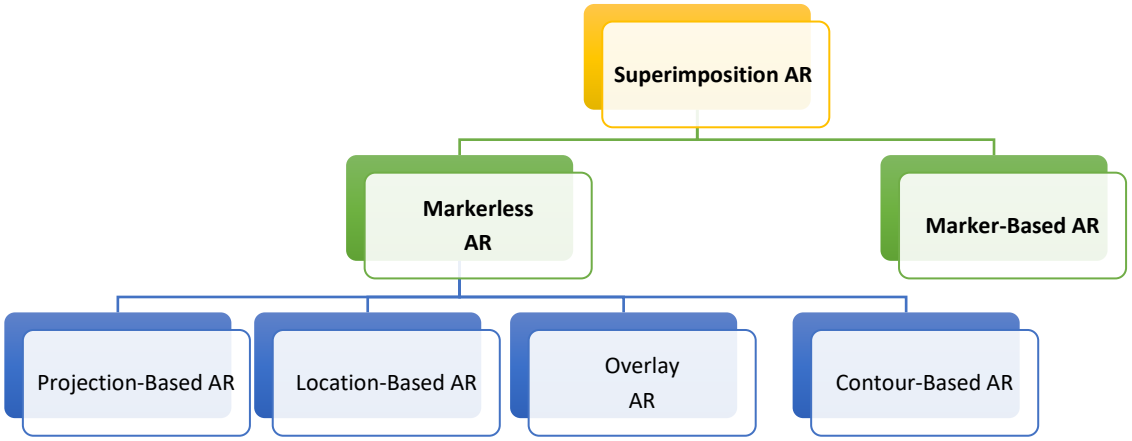
• **Scene Recognition** is used to recognize and track larger structures that exceed table-sized objects.

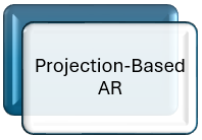
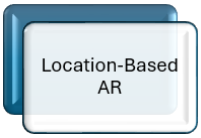
• **Spatial Computing** - is defined as a human interaction with a machine in which the machine retains and manipulates references to real objects and spaces.

• **Target image** and associated extracted data are used by the tracker to recognize an image.

• **Tracking** - The AR experience should "understand and track" where a certain object is placed in the real world to anchor its content.

At the moment, we distinguish several types of augmented reality:



	Markerless requires no image to produce visual effects. This technology uses a device's camera, location software and accelerometer to obtain information about the position and orientation of objects in space. A mobile device with a markerless augmented reality application can be used to recognize images from the cloud or stored on a server. Images must be unique.
	• AR technology based on the projection of light on a flat surface to create 3D images (holograms). • User interaction is achieved by touching the light on the surface and touching the surface on which the interaction is projected.
	• Content is fixed to a specific physical space. • AR does not need a special marker to identify the location of virtual objects. • Works using technologies like GPS, accelerometer, digital compass etc. to pinpoint the location and position of a device. • Pokémon GO is the best-known example of location-based augmented reality.

Overlay AR	• AR replaces viewing an object with an enhanced virtual image of the same item, complete with multiple visual perspectives. • Digital data is superimposed on the actual displayed environment and is designed to interact with it.
Contour-Based AR	• Contour-based AR updates an object's image to a real-time assisted virtual image. • AR creates edges and outlines of less recognizable objects. • AR uses SLAM to contour the object and simulate realistic human interaction. • Contour-based AR is used in navigation systems
Marker-Based AR	• Maker-based AR works by scanning a marker that triggers an enhanced experience (either an object, text, video, or animation) to appear on the device. • The most used markers are two-dimensional QR codes. • Marker-based AR can only be used with mobile devices such as a smartphone or tablet

2.2. Augmented reality hardware

Augmented Reality technology uses two types of hardware interfaces to overlay digital information on the physical world:

a. Heads-worn displays
b. Handheld displays.

Source: https://beyonddesign.typepad.com/posts/bim-360-docs/

a. Heads-worn displays

Head-mounted displays are wearable devices that allow users to view digital content overlaid on the physical world. These devices are designed to provide a hands-free experience, allowing users to interact with digital information without having to use their hands to hold a device. There are several types of head-worn displays, each with its own characteristics and applications.

Types of Head Displays:

• AR glasses: These devices show information directly in the user's field of vision, using projection technology or holograms. They are often used for industrial, educational or entertainment purposes.

Example: Microsoft HoloLens, which allows users to view and interact with holograms in the environment, seamlessly integrating them with real objects.

• AR Headset: This type of hardware is larger and provides better coverage of the field of view. AR headsets can include a variety of sensors for gesture and environment recognition.

Example: Magic Leap One, which uses advanced technology to place holograms in physical space, giving users a fluid and natural interaction.

Advantages:

• High Immersion: Gives users an immersive experience, allowing them to interact with digital content directly in their environment.

• Discretion: Allows users to access information without having to stop or focus on a device, which is ideal in professional applications.

Challenges:

• Comfort: Some devices can be bulky or uncomfortable when worn for longer periods.

• Costs: The advanced technology used in these devices can be expensive, limiting their affordability

b. Displays for the Hand

Handheld displays are smaller, portable devices that allow users to interact with digital information at their fingertips. These may include smartphones, tablets or special controllers designed for AR applications. Handheld displays also allow users to view and control digital content in a more interactive way.

Types of Handheld Displays:

• Smartphones and Tablets: These devices are most used for AR applications due to their advanced cameras and sensors.

Example: AR apps like Pokémon GO or Snapchat that use the device's camera to overlay virtual objects onto the real environment.

• AR Controllers: These allow users to interact with digital objects through gestures or physical buttons, providing a more immersive experience.

Example: Controllers used with AR devices, which can simulate interactions with virtual objects, facilitating their manipulation.

Advantages:

• Accessibility: Users can quickly access AR applications without the need for expensive or complex equipment.
• Interactivity: These enable a greater level of interaction as users can use gestures and movements to manipulate digital content.

Challenges:
• Screen Limitations: The size of the screen can limit the user experience compared to the experiences offered by head-up displays.
• Need for Hands-Free: Although smartphones and tablets are easy to use, users may need a free hand to interact with content

2.3. Augmented reality software

Augmented reality (AR) software is essential for developing and deploying applications that integrate digital content with the real world. It allows the generation, processing and display of virtual elements in real-time using available hardware. There are several types of AR software, each with specific features and different purposes.

a. AR Development Platforms

AR development platforms provide tools and resources for programmers and developers to create AR applications. These platforms provide code libraries, SDKs (Software Development Kits), and tutorials to facilitate the development process.

Examples:

❖ **ZAPPAR**: Zappar is an AR development platform because it allows users and developers to create and publish AR content using their own tools and templates but also provides APIs and development tools that make it easy to integrate augmented reality functionality into apps and websites (category 5 software).

https://www.zappar.com/

❖ **ARKit**: A platform developed by Apple that allows developers to create AR apps for iOS. ARKit offers advanced surface detection, facial recognition, and motion tracking features.

https://developer.apple.com/augmented-reality/arkit/

❖ **ARCore:** Similar to ARKit, but developed by Google for Android devices. ARCore enables the development of applications that integrate digital content with reality through position tracking, plane detection and illumination estimation.

https://developers.google.com/ar

❖ **Wikitude**: An AR platform that provides development solutions through an SDK, enabling the creation of location-based AR applications and image recognition.

b. 3D modelling software

3D modelling software is used to create virtual objects and animations that can be integrated into AR experiences. This type of software allows designers to create detailed models that can be overlaid in real time over the physical environment.

Examples:

❖ **Blender:** An open-source software used for 3D modelling, animation and rendering. Blender is often used to create AR content because of its advanced features and accessibility.

https://www.blender.org/

❖ **Autodesk Maya** (Pro, free for students): A professional software used in the industry for 3D modelling, animation and simulations, also useful for creating AR content.

https://www.autodesk.com/

❖ **SketchUp** (Free with paid options)

https://www.sketchup.com/en

❖ **Tinkercad** (free)

https://www.tinkercad.com/

❖ **Fusion 360** (free for students, paid options):

https://www.autodesk.com/products/fusion-360/

c. Image recognition software

Image recognition software is crucial for identifying real-world objects and integrating them with digital content. It allows AR apps to analyse what devices' cameras "see" and react accordingly.

Examples:

❖ **Vuforia:** An AR development platform that provides advanced image recognition and 3D object tracking. Vuforia is frequently used in commercial and educational applications.

vuforia engine™ https://www.ptc.com/en/products/vuforia/vuforia-engine

❖ **OpenCV** (free): An open-source library used for image processing and computer vision. OpenCV can be integrated into AR applications to facilitate image recognition and analysis.

https://opencv.org/

❖ **Clarifai** (Free with paid options):

clarifai https://www.clarifai.com/

❖ **Microsoft Azure Computer Vision** (Free with limitations, paid options):

https://azure.microsoft.com/en-us/products/ai-services/ai-vision/

❖ **Google Cloud Vision API** (Free with limitations, paid options)

Google Vision API https://cloud.google.com/vision/

d. Mixed reality integration software

Mixed reality integration software allows elements of augmented and virtual reality to be combined, giving users a richer experience. This type of software allows users to interact with digital objects in a way that simulates interactions with physical objects.

Examples:

❖ **Microsoft Mixed Reality Toolkit** (MRTK): A collection of resources for developers creating mixed reality applications, facilitating interaction with virtual environments.

https://github.com/microsoft/MixedRealityToolkit-Unity

❖ **Unity:** A game engine that supports the development of AR and VR applications, with dedicated tools for integrating elements from both types of reality.

❖ **ARKit (only free for iOS):**

https://developer.apple.com/arkit/

❖ **HoloLens Development Kit (Pro, needs HoloLens):**

https://developer.microsoft.com/en-us/windows/mixed-reality/

❖ **OpenXR (free):**

https://www.khronos.org/openxr/

e. APIs and development tools

APIs and development tools make it easy to integrate and use AR features in applications. These tools reduce development complexity and allow developers to quickly integrate AR functionality.

3. Hands-on Practical training in AR Technology

3.1. How to start? Create a ZappAR account

Link: https://my.zap.works/projects/

Zappar and ZapWorks are two components of the same ecosystem, but they have different functions and purposes.

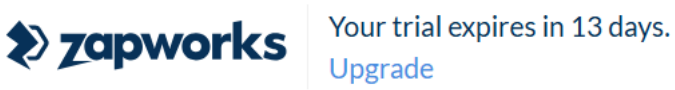
Zappar is an augmented reality (AR) application available on mobile devices that allows users to interact with AR content by scanning Zapcodes or other markers. Users can discover and view AR content such as animations, videos and 3D objects. It is an easy-to-use platform for consumers who want to experience AR without requiring advanced technical knowledge.

ZapWorks is an AR development platform that provides tools and resources for developers and designers to create custom AR content such as 3D animations, videos and interactions. The platform includes a visual editor (ZapWorks Studio) and other tools for developing complex AR applications.

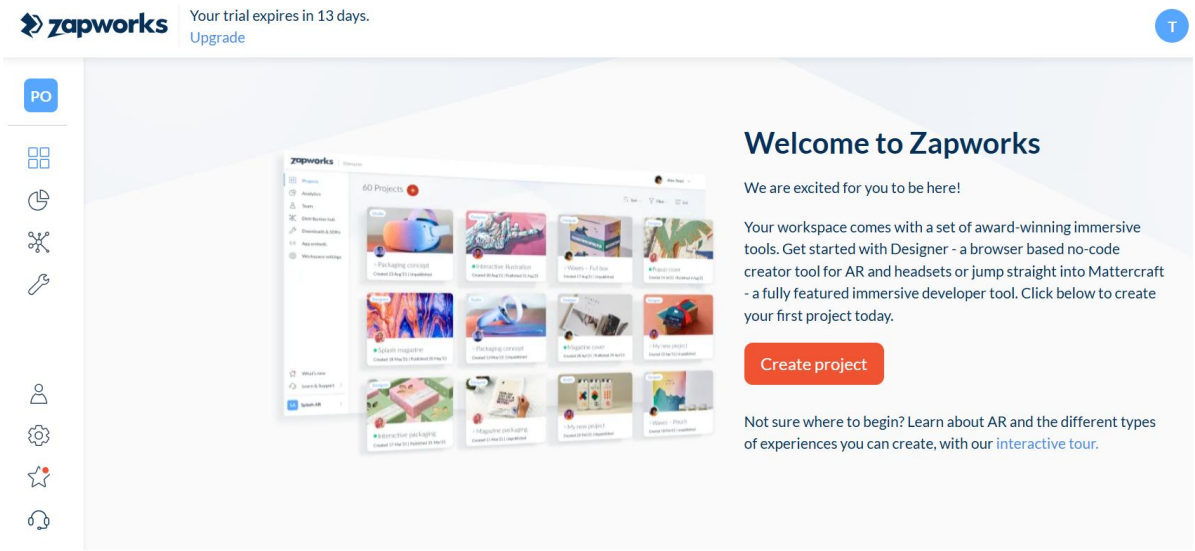
Otherwise:

- Zappar is the mobile app for end users who want to interact with AR content.
- ZapWorks is the development platform that provides tools for creating custom AR content for developers and designers.

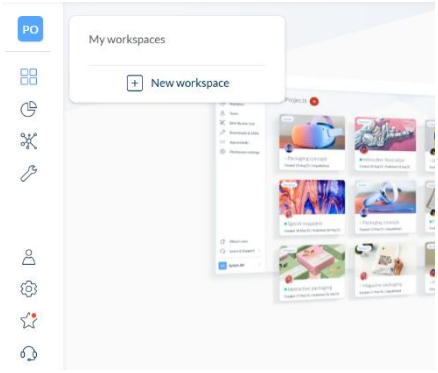
The Zapworks platform offers several PRO login options, but for the free version we only have 13 days.

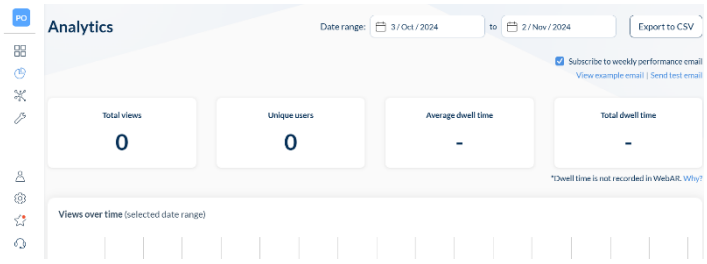


After opening the direct account, we have the following home page:

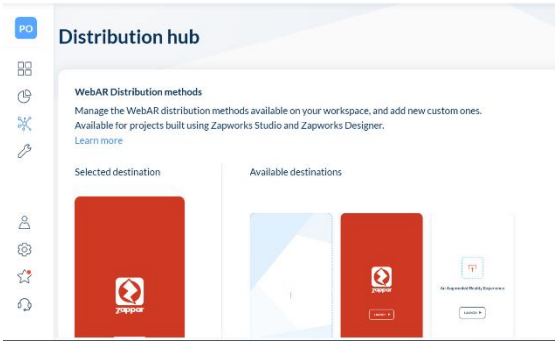


We have at our disposal the Menu on the left:

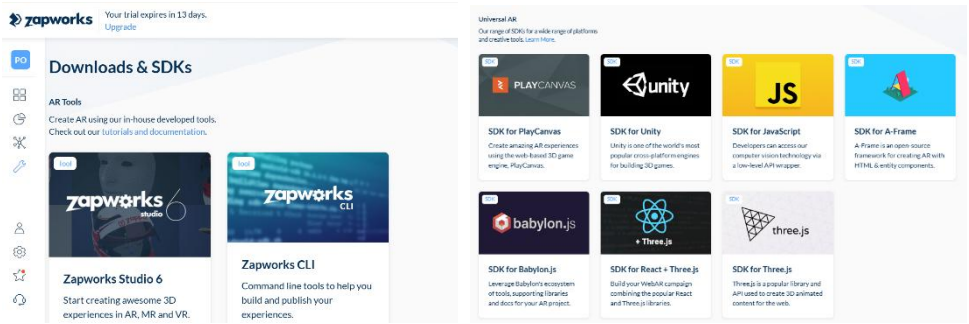




where we can see the statistics, after we access the AR create apps,



ways of distributions,



but also, the modules we can download.

From the main page, we are offered a tour through the application galleries that the platform offers in the three major categories to guide us later when we leave a project:

Face tracking uses computer vision to build an understanding of a users' face: recognising key landmarks such as the eyes, mouth, nose, and chin. By understanding where these landmarks are, we enable you to build interactive experiences by attaching 3D models and 2D images to them.

In addition, we also know when a user completes certain actions, such as raising their eyebrows or opening their mouth, which opens a range of use cases:

- Virtual product try-ons (e.g. sunglasses)
- Drive social shares with selfie photo booths
- Create fan engagement experiences

World tracking allows us, through the phone camera, to build an understanding of a user's environment, and place digital content on to flat surfaces. The position of content placed in the world is often set to remain fixed, allowing users to walk around and view it from any angle, making it feel like it is part of the room with you.

You should use world tracking if you want to:

- Create a portal for users to 'step' into
- Visualise people & products in the real world
- Create room-scale mini-games

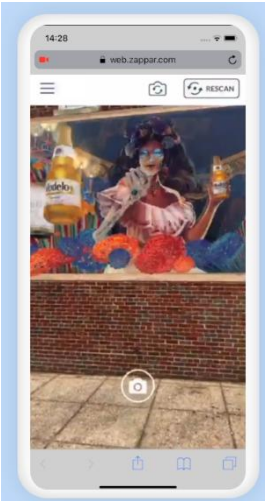


Image Tracking

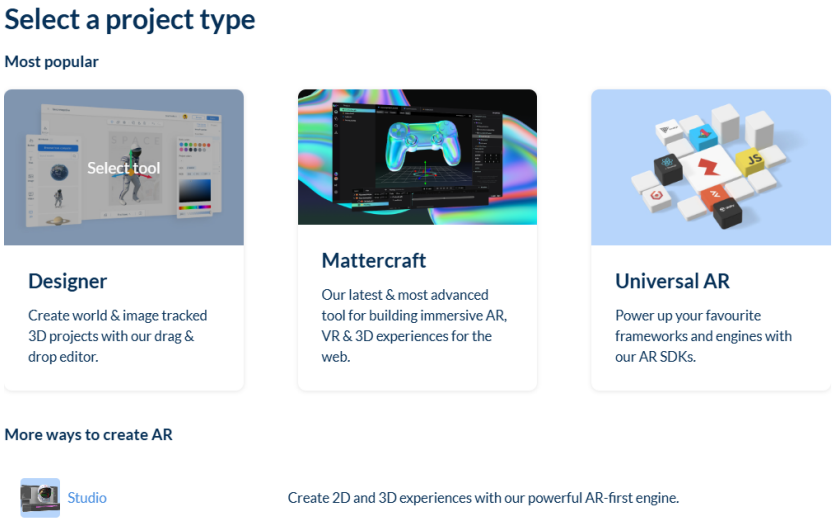
Printed materials such as posters and magazine covers can be uploaded to ZapWorks to make ' Target images '. Using our image tracking technology, through the phone's camera, you can bring these materials to life.

You should use image tracking if you want to:

- Create an interactive magazine or book
- Build a mini game tracked to a cereal box
- Connect product packaging to eCommerce stores

3.2. Platforms to Create Augmented Reality - ZapWorks Studio

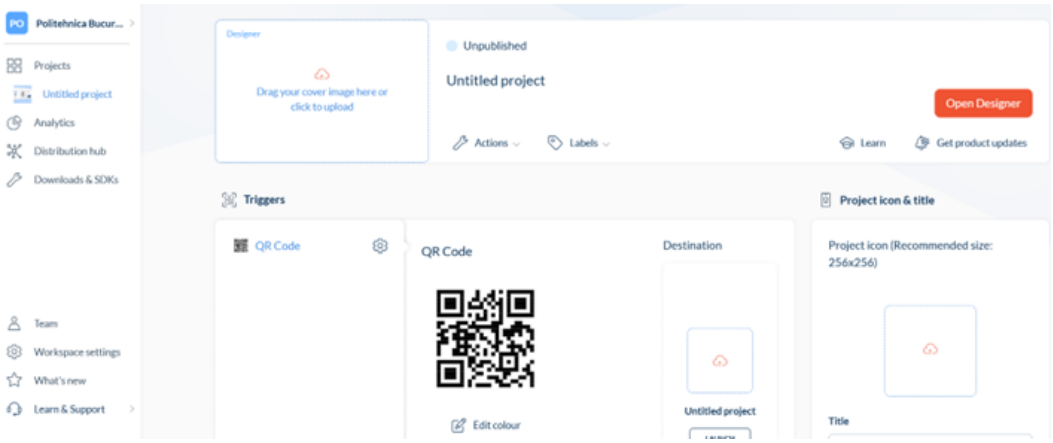
A brief overview of the ZapWorks Studio platform: The platform offers us 4 options to create an AR app: **Designer**, **Mattercraft**, **Universal AR** and **Studio.**



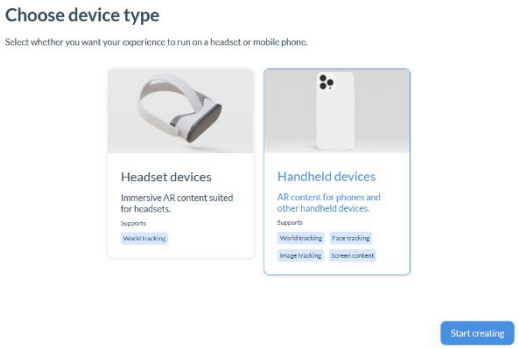
Regardless of which option we choose, the first window is identical, later after pressing the Open Designer/ Mattercraft/ Studio button, the option windows are different

A. DESIGNER interface

Zapworks Designer is a browser-based, no-code immersive experience development tool. Designer gives you the platform to easily create stunning WebAR (Augmented Reality) and WebXR (Mixed Reality) experiences without coding expertise.

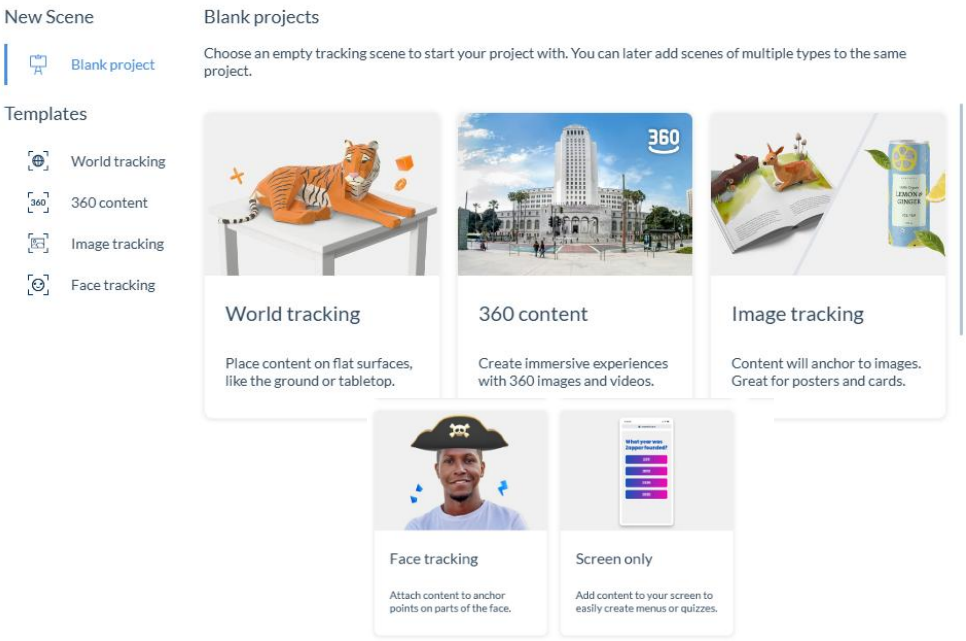


Within this variant, we must decide for which hardware equipment we apply:



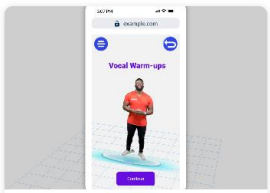
zapworks Designer

Afterwards we have to decide which content we choose as a template/model:



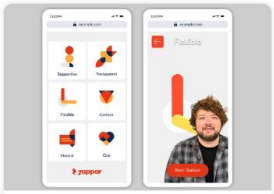
Thus, for each category we have several models that we can use and develop/ modify:

World tracking templates:



Public Speaking skills

Tips and exercises to speak confidently in public.



Company Values

Learn about the company values of Zappar.

Mastery Loop (L&D)

Watch a video and answer questions to proceed.

Tourism promo

A city and language promo using alpha video.

Honey promo

Use curved tracking to promote your product.

Beverage promo

Use curved surface and alpha video to promote a product.

Product showcase

Showcase product features using alpha video.

Treasure hunt

A treasure hunt experience using all three tracking types.

Expanding watch

Animated product that expands when you tap.

Headphones promo

Visualise your product in an immersive experience.

Drink promo

Visualise a product in world tracked space.

Guitar Shop Promo

AR-enabled marketing material for a guitar store.

Product Hotspots

Visualise and interact with a product via hotspots.

Onboarding (L&D)

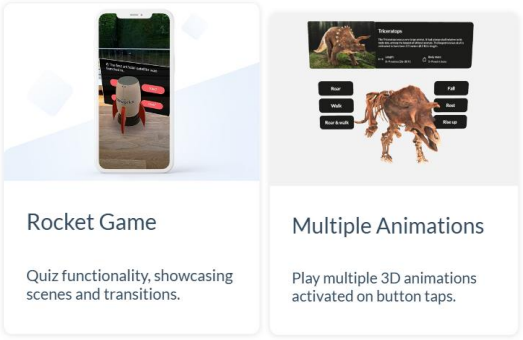
Showcase of an employee onboarding experience.

3D Model (World)

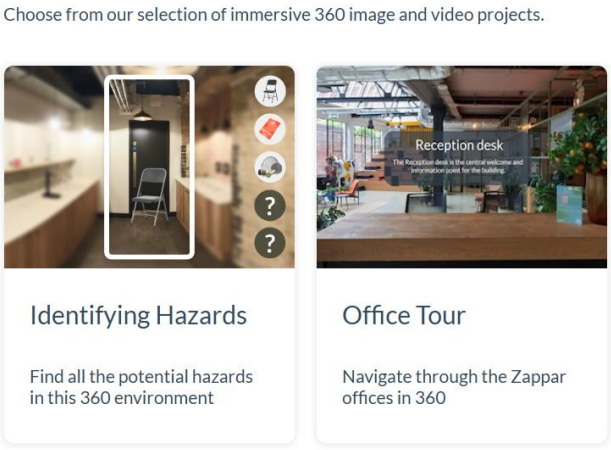
Simple experience containing a world tracked 3D model.

Animated Avatar

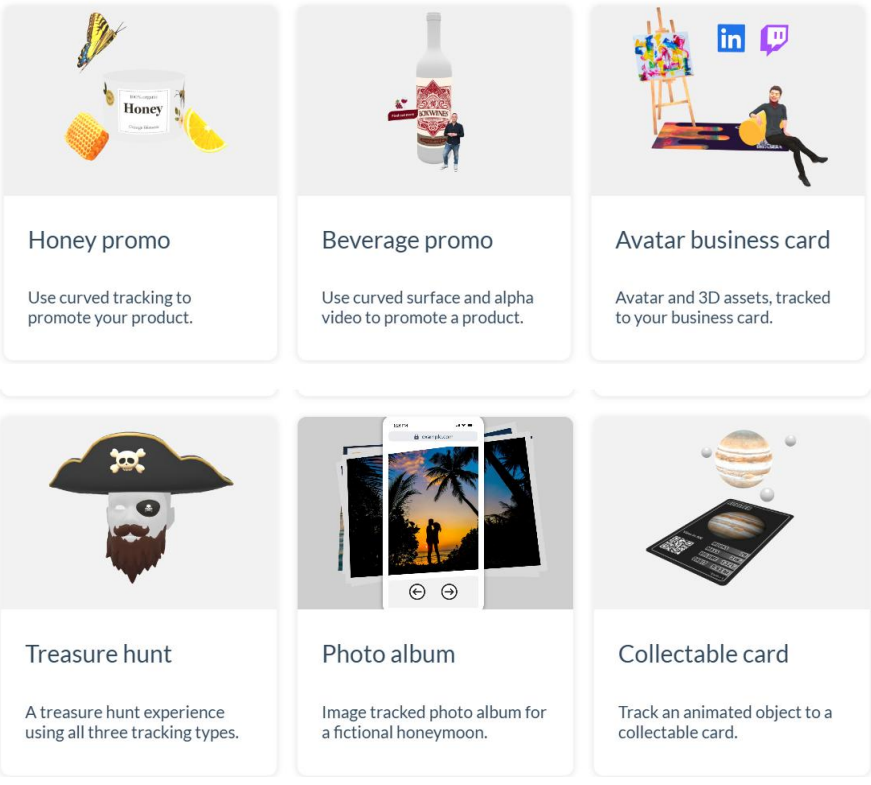
World tracked animated 3D avatar (Ready Player Me).

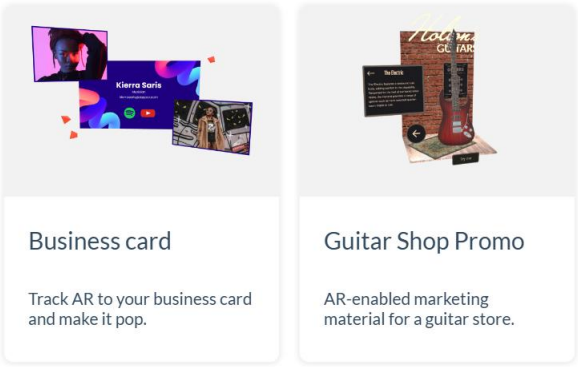


For the option **360 content**

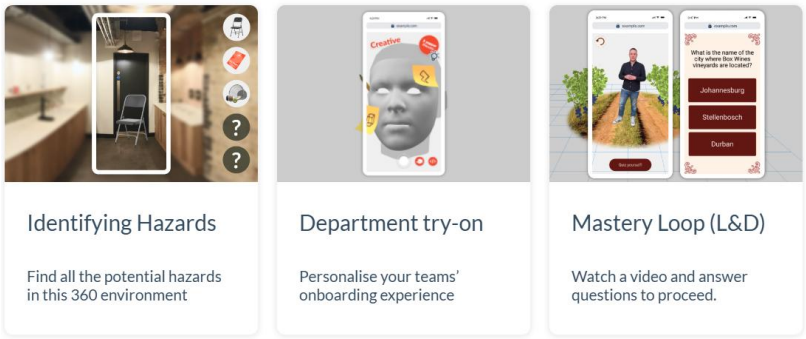


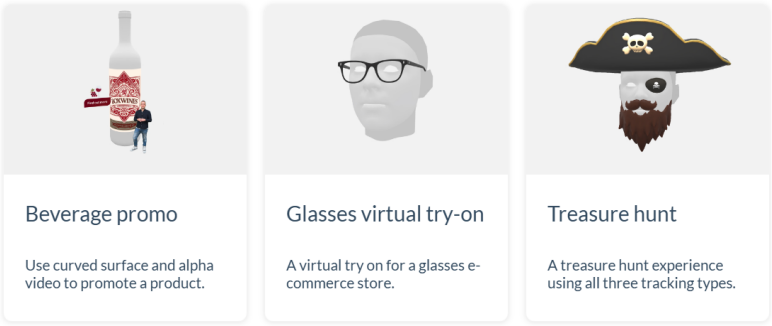
For the option: ***Image tracking*** we have the next templates



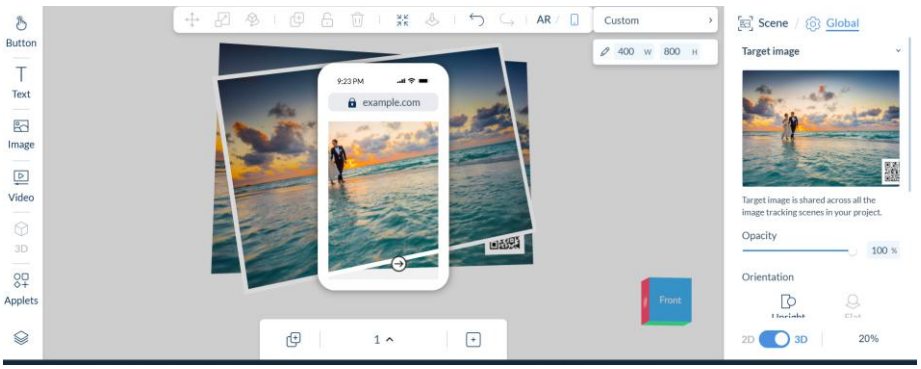


Face tracking offers us other models/ templates



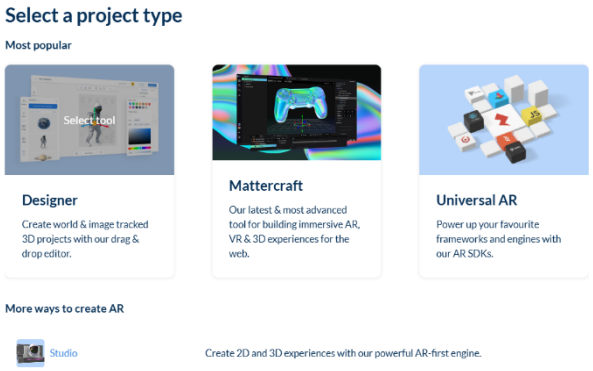


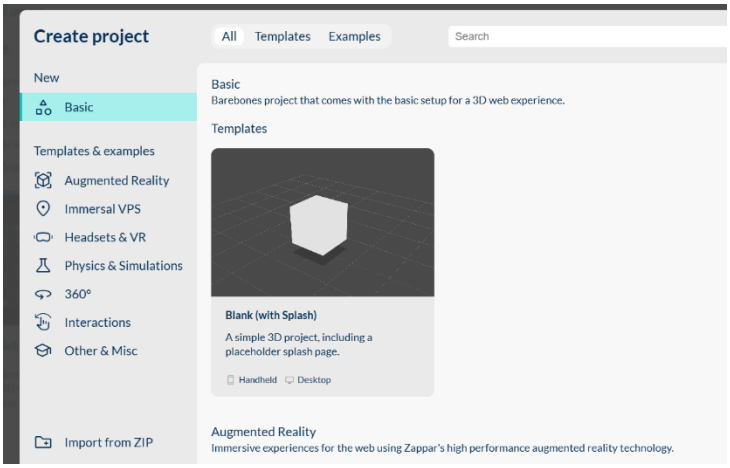
Regardless of the chosen template, the following window will open where the AR application is edited and built:



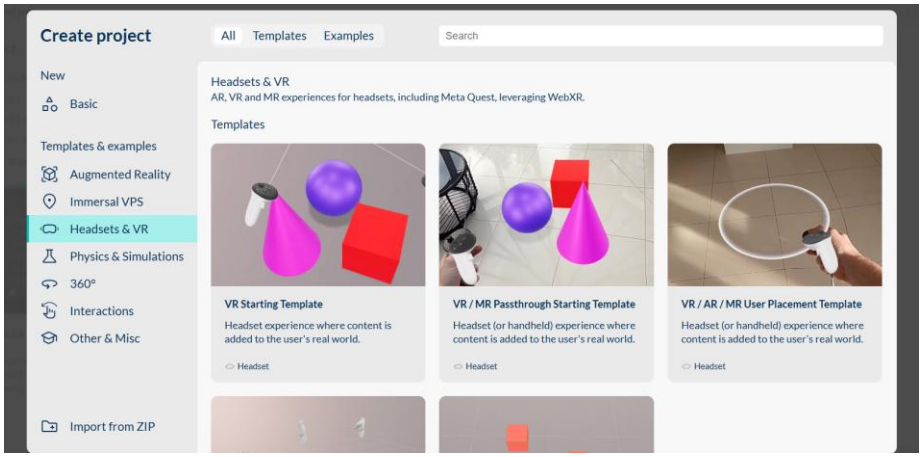
B. Mattercraft interface

Mattercraft is a fully integrated, browser based 3D content development environment perfected for building interactive experiences for the web. Mattercraft's intuitive 3D editor lets you create web experiences visually, while leveraging the best features the web has to offer.

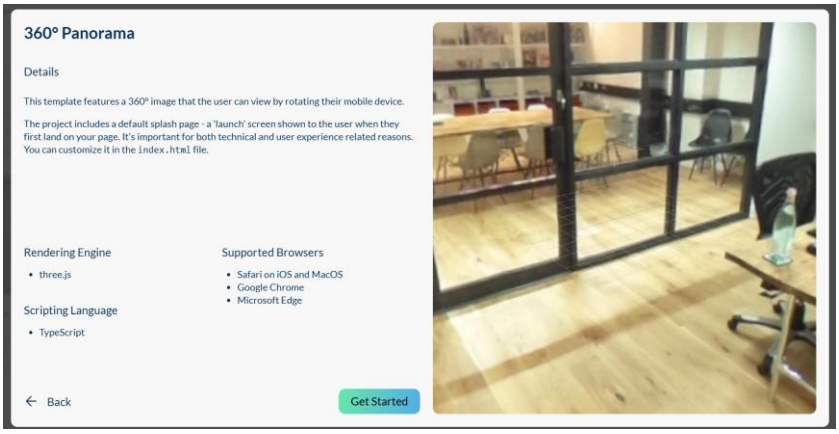


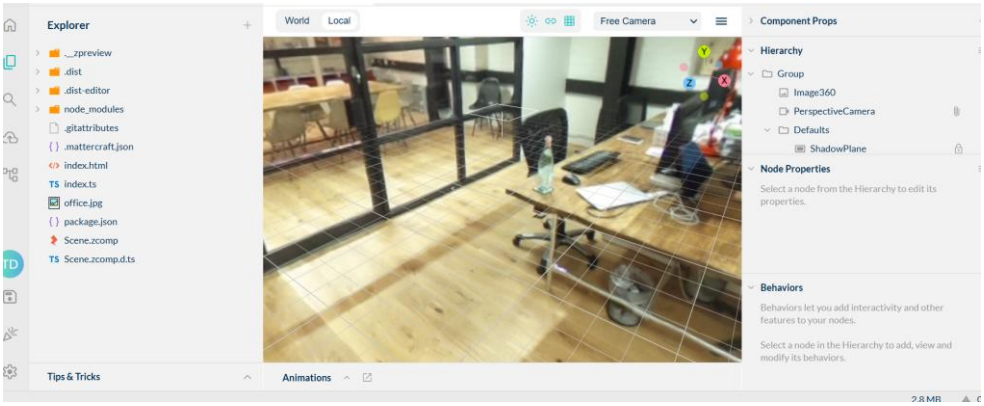


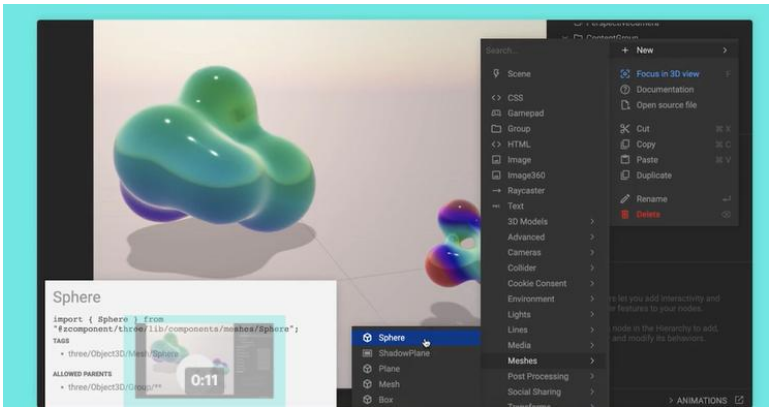
Mattercraft offers support for immersive World, Face, and Image tracked Augmented Reality experiences. Powered by Zappar's cutting-edge tracking technology, Mattercraft enables you to



With Mattercraft, it's possible to build immersive virtual, mixed and augmented reality experiences for deployment to headsets and handheld devices over the web.





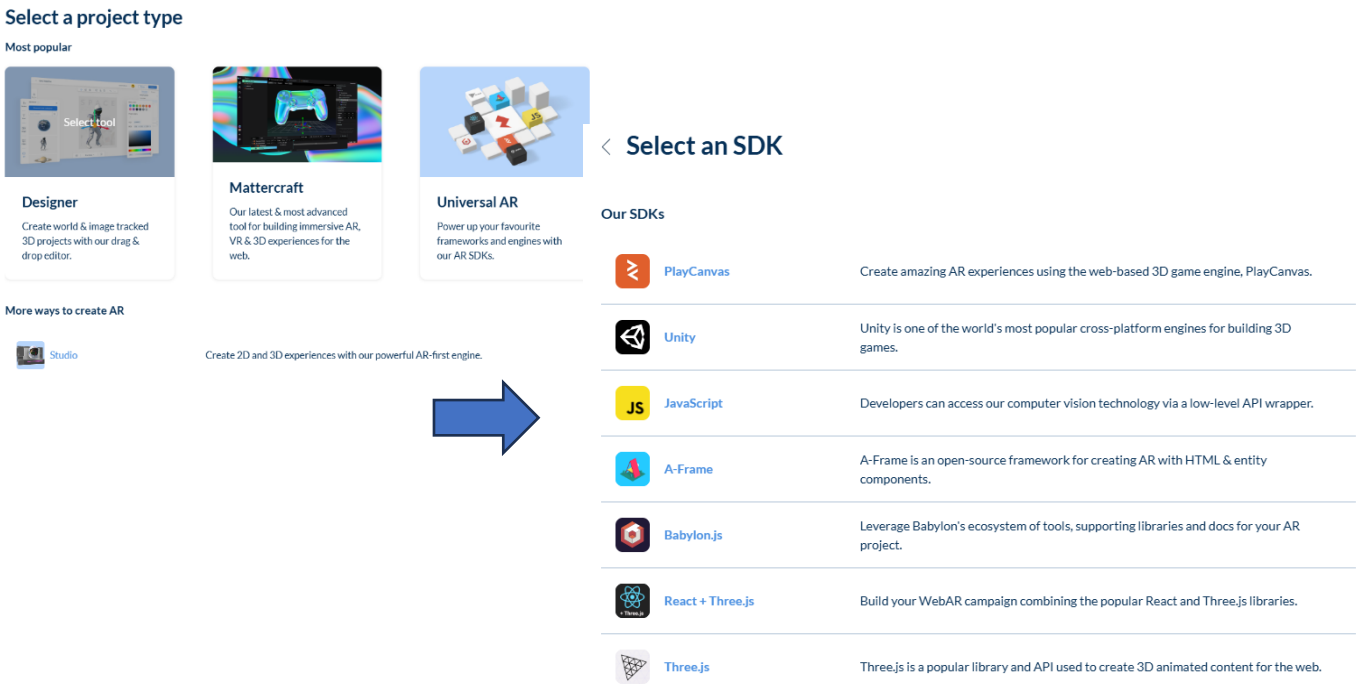


Mattercraft Zappart:

- 3D AR Content Creation: Mattercraft Zappart allows users to create and integrate complex 3D models into augmented reality experiences, facilitating the use of interactive objects directly from the 3D environment.
- Gamification Features: This module includes options for implementing gamification elements such as scores, levels, and interactive feedback, which are not predominantly featured in the other modules.
- Advanced User Interface Customization: Mattercraft Zappart offers advanced options for customizing the user interface in AR applications, allowing developers to fully adapt the look and functionality of the application to meet their specific user needs.
- AR Data Analytics System: Zappart includes integrated tools for monitoring the performance of AR applications, enabling developers to better understand how users interact with the content and optimize the experience.
- Support for Collaborative Augmented Reality: Mattercraft Zappart allows for real-time AR interactions between users, facilitating collaborative experiences that are not available in the other modules.

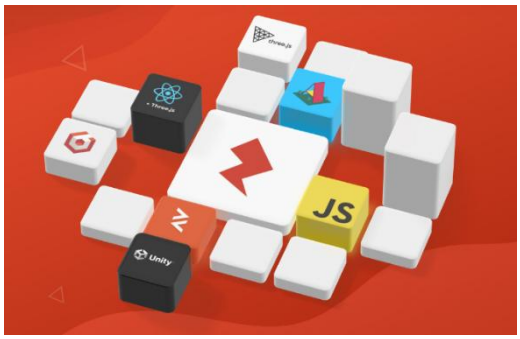
These features make Mattercraft Zappart ideal for developing more sophisticated AR applications, enabling users to create innovative and engaging experiences.

C. Universal AR interface



The Universal AR Interface module in Zappar AR offers several unique features that differentiate it from the other three modules (Designer, Studio, and Mattercraft):

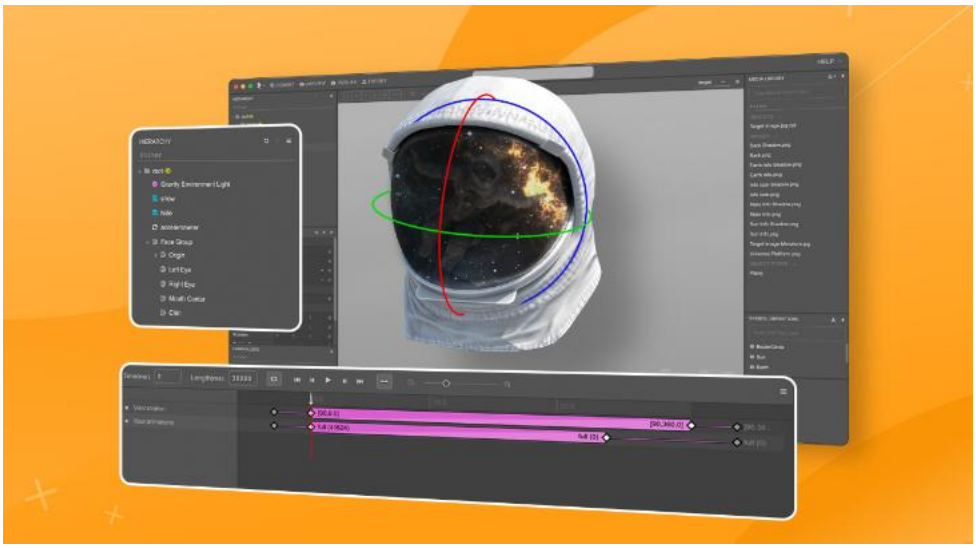
- Flexibility and Adaptability: The Universal AR Interface is designed to be highly flexible, allowing developers to build AR applications that can quickly adapt to various types of content and interactions, unlike the more specialized modules.
- Customizable Interactions: This module provides advanced options for customizing how users interact with AR content, including gestures, touches, and voice commands, which may not always be available in the other modules.
- Easy Content Integration: The Universal AR Interface facilitates the rapid integration of different types of content, such as animations, 3D models, and visual effects, while maintaining a consistent user experience.



- Support for HTML and WebAR: Unlike the other modules, which may focus more on native applications, the Universal AR Interface offers support for WebAR, enabling developers to create AR experiences that are accessible directly through web browsers.
- Unified Interface: This module provides a unified interface that streamlines the development process, allowing users to create and deploy AR applications more quickly and efficiently, regardless of their complexity.
- Accessibility and Ease of Use: The module focuses on providing an easy-to-use experience for both developers and end-users, making it simpler to create AR applications without the need for advanced programming skills.

Universal AR is Zappar's best-in-class computer vision libraries (including image, face and instant world tracking) available as SDKs for a wide variety of platforms and languages.

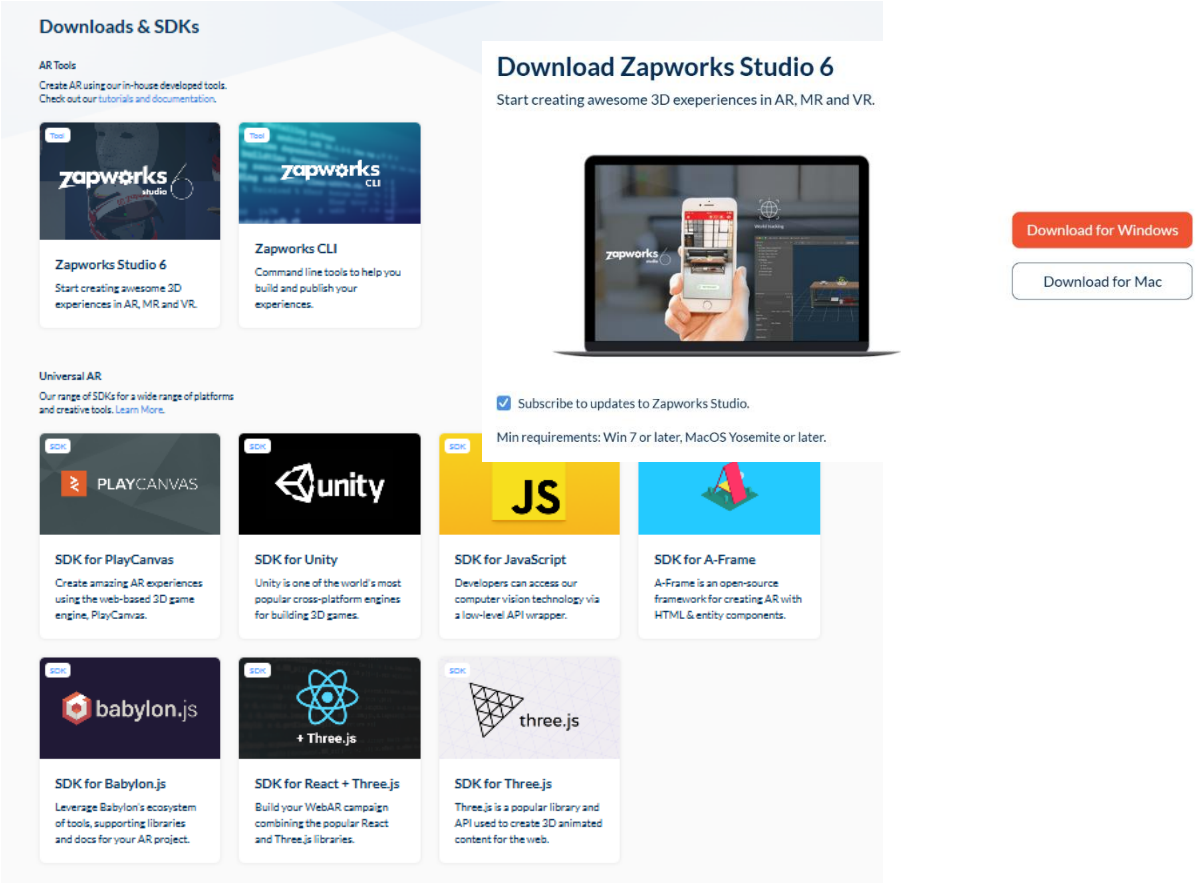
D. STUDIO interface



Zapworks Studio allows you to create fully customizable augmented reality experiences. With support for image-, face-, and world tracking, 3D models, and custom animations.

ZapWorks Studio's world tracking functionality allows you to position digital content in the user's real-world environment.

The position of content placed in the world will remain constant, allowing users to walk around, and view, the content from any angle. **World tracking builds upon ARKit and ARCore technologies and must be launched in the Zappar app or custom app equivalent to function correctly.**



World-tracked experiences require the target device to support ARKit (iOS) or ARCore (Android).

ZapWorks Studio provides a number of project templates, accessible from the **New Project** modal. These include projects which demo certain functionalities, as well as templates that can be modified by swapping in your own assets.

Modification notes are displayed when a project template is opened in Studio, and provide instructions on how to correctly edit the project.

While **Actions** make it easy to add interactivity, ZapWorks Studio provides the ability to define custom functionality and behaviour for full control over your experiences, through its **TypeScript** environment. Studio's script editor also provides a number of shortcuts to help speed up your development workflow.

The Studio module offers several unique features that set it apart from the other three editing modes (Designer, Mattercraft, and Universal AR Interface):

- **Comprehensive Editing Tools**: Studio provides advanced editing tools that allow for in-depth customization of AR experiences, including features for manipulating 3D objects, animations, and interactions in a more granular way than other modules.
- **Enhanced 3D Content Creation**: Studio focuses on 3D content development, enabling users to create, import, and edit 3D models directly within the platform, which is not as prominently featured in the other modes.

- **Animation Capabilities**: The Studio module includes robust animation tools, allowing developers to create complex animations and transitions for AR objects that can enhance user engagement, something that may be limited in the other editing modes.
- **Scripting and Logic Integration**: This module supports scripting capabilities, allowing users to add custom logic and functionalities to their AR applications, enabling dynamic interactions and behaviors that are not available in the more template-driven modules.
- **Multi-User Collaboration Tools**: Studio encourages collaborative development, providing features that facilitate real-time collaboration among team members working on the same AR project, which may not be as effectively handled in other modules.
- **Testing and Debugging Functions**: Studio offers integrated testing and debugging tools, enabling developers to evaluate their AR experiences within the environment before deployment, which enhances the quality assurance process.

These unique features make the Studio module particularly suitable for developers looking for a comprehensive and customizable environment for creating sophisticated AR applications, distinguishing it from the other editing modes in Zappar.

3.3. Example of AR in Zapworks Designer

Zapworks Designer is a browser-based, no-code immersive experience development tool.

After selecting the type of device for which we are creating the AR application (Headset or handheld devices), we choose the type of desired AR experience and the associated template. In this example, we select **Image Tracking**.

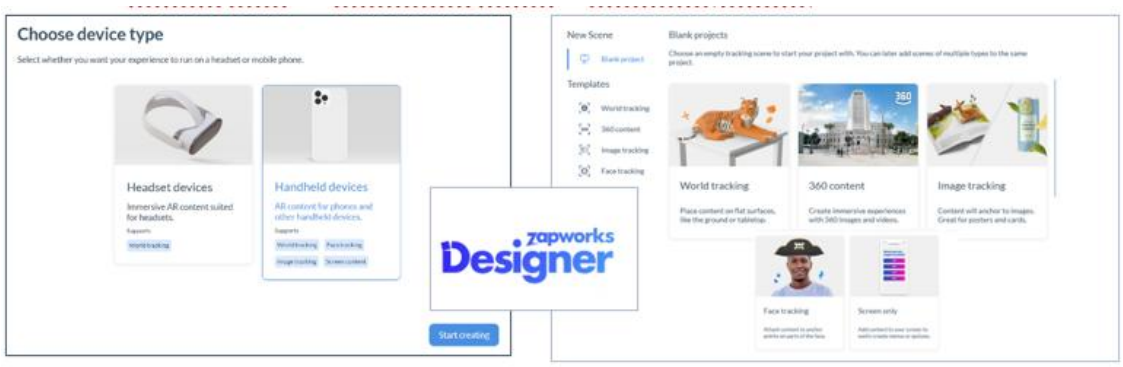
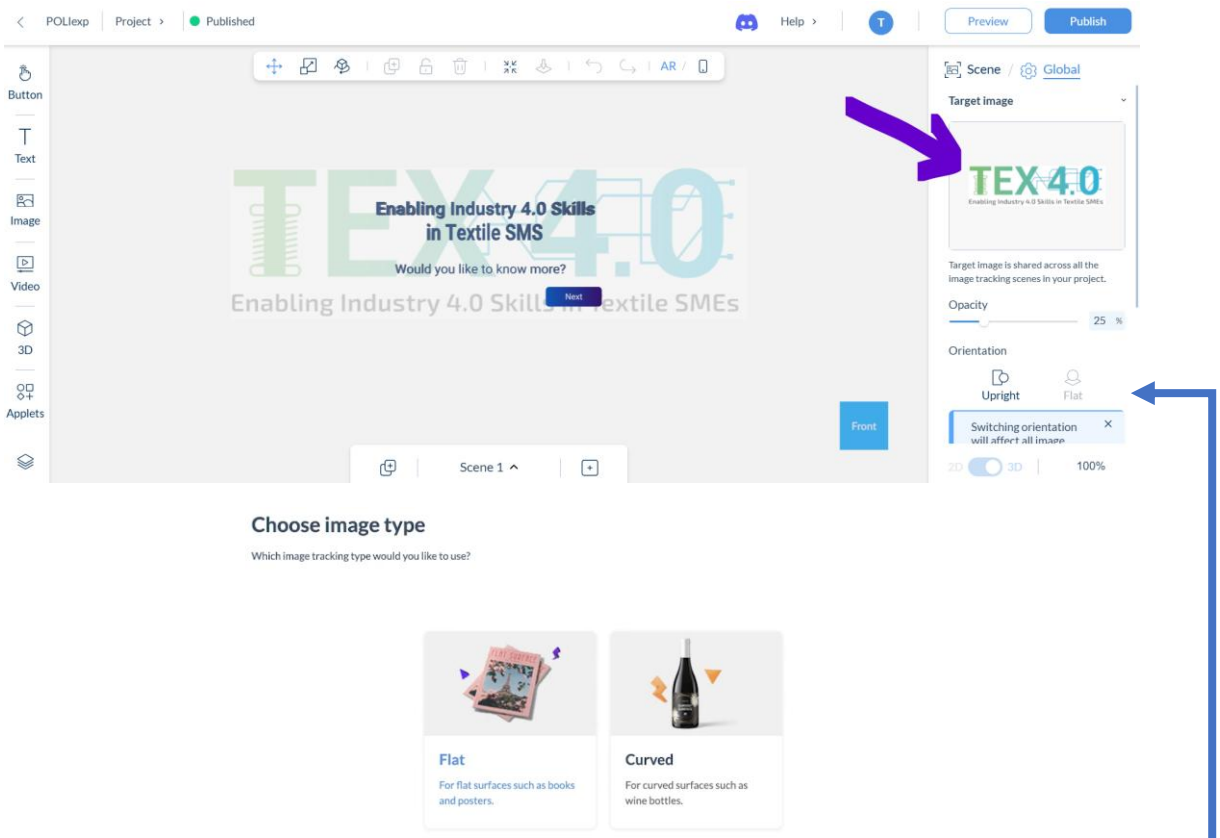


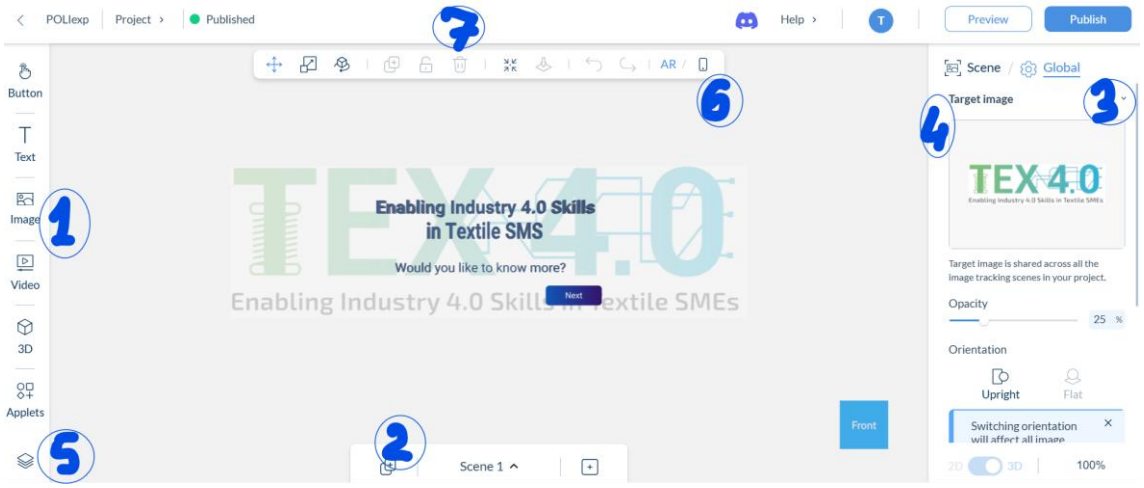
Image Tracking can detect and track digital content to a flat or upright image. This is great for building content that's augmented onto print material such as business cards, posters, and magazine pages.

Upon selecting **Image Tracking**, you'll be prompted to upload a **target image** in which your content will track to. To do this, select the **Upload target image** button in the **Project Properties** panel. Your target image will be trained, and once uploaded, will appear on your canvas.

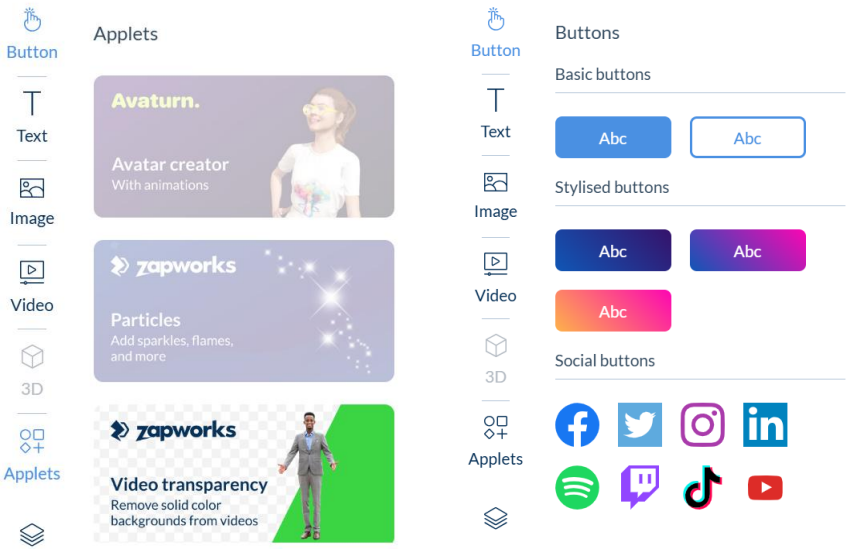


You are also able to choose whether the image you track to is oriented in the **Upright** or **Flat** position through the **Project Properties** panel.

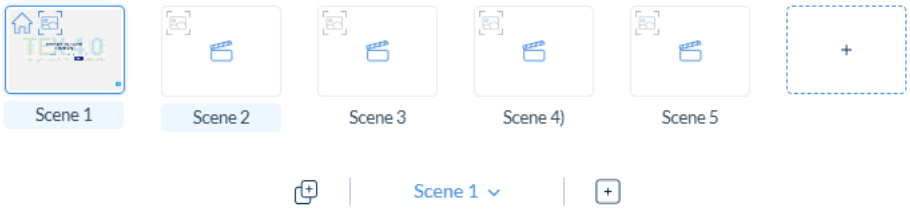
Zapworks Designer is made up of a number of different panels, each of which are essential when developing experiences.



1. **Components Panel:** The components panel shows digital elements that you can add to your scene. Here you can find Button, Text, Image, Video or import a 3Dmodel.
   In this AR application, a button has been added to each scene, along with at least one piece of text.



2. **Scene Manager Panel:** the scene manager panel alters the properties of the scenes in your project(Select which scene is currently displayed in the viewport; Change the name of your scene by selecting on your scene name, or via the burger menu, on the scene selection menu; Adds another scene to your project or Duplicates the scene that is currently being viewed.)

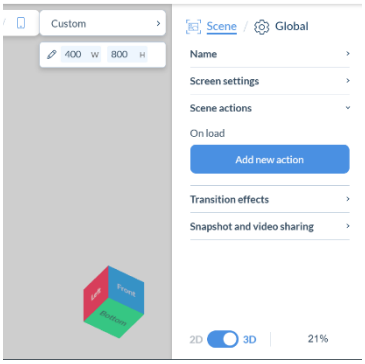


In this AR application we have 5 scenes, each launched by pressing a button from the previous scene.

3. **Global Properties** The project properties section is for making changes to your overall project. Here you can find:

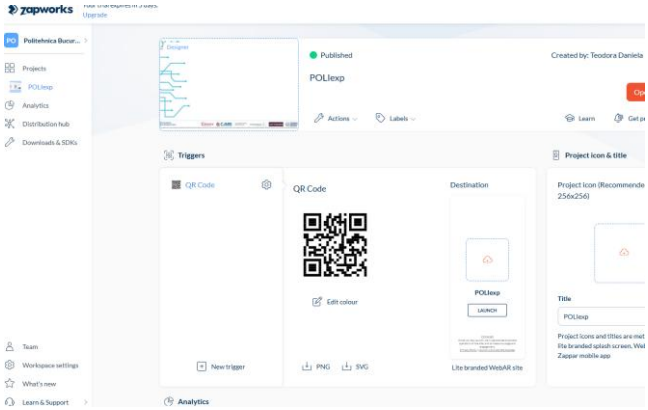
Section	Description
Upload Target Image	Upload the image you wish for your project to be tracked to.
AR Web Embed	Embed your Zapworks Designer projects into a website.
Shadow Settings	Enable shadows for 3D components in your project .
Background Sound	Add some background sound that plays when a user views your experience.
Scene Properties	Edit the name and view the content of the scene.
Scene Transitions	Add a transition that plays when you move between scenes.
Photo UI	Toggle the camera controls for saving and sharing your scene.
Zoom	Determines how zoomed in or out the scene viewport is.
2D-3D Switch	Change between a 2D and a 3D view.

4. **Scene Properties**
The scene properties section is for making changes to the specific scene you're on(add a transition that plays when you move between scenes; toggle the camera controls for saving and sharing your scene)



5. **Scene Objects Panel -** Selecting an object from the list will also update the selection in the scene. This is great for quickly selecting objects that are overlaid by others.
6. **Context Bar -** the context bar allows you to manipulate components and switch between AR or Screen UI mode (Move or rotate the selected component in the X, Y, or Z axis; Duplicate or delete the selected component; Recenter your view on the canvas to defaults; Lock or unlock the selected component from transform functions, etc).

7. **Action Bar -**contains admin functions for your project:
   - ❖ Rename the project on your workspace by double clicking on the current name.



   - ❖ Replace the current project with a template.
   - ❖ Open a drop-down menu with links to view shortcuts, see what's new, find helpful documentation, and send feedback.
   - ❖ Shows the users that are currently editing the project.
   - ❖ Generates a temporary QR code to scan and view your current version.

   - ❖ Publishes your project so anyone with the project trigger to access your project.

The project can be added to or modified at any time by adding or deleting scenes, objects, or actions. Each operation must be finalized by publishing it, ensuring that any changes are visible/active in the AR application.

4. AR Based Business Models

4.1. Introduction to Business Models based on AR

Augmented Reality (AR)-based business models in the textile industry and associated applications like 3D printing significantly transform how consumers interact with products. By using AR, companies can offer personalized, engaging, and educational experiences that not only enhance customer satisfaction but also contribute to increased sales, brand loyalty, improved customer interactions, optimized internal processes, innovative product development, and better marketing.

An AR-based business model must consider the following fundamental aspects:

- **Campaign Objective**: What does the company offer users with AR?
- **Customer Segmentation**: Who are the targeted customers for AR-based products or services?
- **Distribution Channels**: How do products/services reach customers?
- **Revenue Streams**: How does the company generate profit from AR?
- **Costs**: What are the costs associated with implementing and maintaining AR solutions?

The architecture of an AR-based business model involves a complex approach, incorporating all these five aspects.

Campaign Objective: What does the company offer users through AR?

In selecting a business model, it is essential to choose one or more specific benefits that a company offers its customers through AR technology. These may include:

- *Interactive Experiences*: AR can transform how consumers interact with products. For example, users can “try on” clothing virtually or view furniture in their homes.
- *Campaign Personalization*: Providing interactive customization options allows customers to create products that reflect their style.
- *Detailed Information*: Through AR applications, customers can access additional information about products, such as user instructions, reviews, or technical details, presented directly in their environment.
- *Improved Purchase Decisions*: AR helps consumers make more informed decisions, reducing waste and enhancing customer satisfaction.

Customer Segmentation: Who are the targeted users?

Customer segmentation is a critical step in selecting a business model, aimed at defining the specific groups to which AR-based products or services are targeted. In the AR field, we distinguish four main customer categories:

❖ *Young Consumers*: Younger generations, more receptive to digital technologies, can be a primary target, especially for fashion and electronics products.

❖ *Online Shoppers*: Users who prefer online shopping and seek interactive experiences can benefit from AR applications that enhance the buying process.

❖ *Technology Enthusiasts*: People interested in innovations and gadgets may appreciate AR solutions that offer new ways to interact with products.

❖ *Retail Companies (B2B):* Companies looking to modernize the shopping experience they offer their customers by integrating AR technology in stores or online platforms.

Distribution Channels: How do products reach customers?

Distribution channels contribute to the success of a chosen business model, referring to how products or services are delivered to customers, such as:

❖ *Mobile Applications*: Offering specific apps that allow users to access AR features, either to view or customize products.

❖ *E-commerce Websites*: Integrating AR solutions on websites that enable customers to view and interact with products available for sale.

❖ *Physical Stores*: Using AR installations in physical stores where customers can access augmented experiences to explore products.

❖ *Social Media:* Platforms like Instagram or Snapchat provide AR options for product marketing, allowing users to interact with brands in a new and engaging way.

Revenue Streams: How does the company make money from AR?

Revenue streams refer to how the company generates income from using AR. These may include:

❖ *Direct Sales*: Income from selling products that integrate AR (e.g., customized clothing).

❖ *Subscriptions*: Subscription-based business models allowing users access to premium AR functionalities through applications.

❖ *Digital Products*: Selling digital products or AR content (e.g., custom AR filters, 3D models).

❖ *Marketing Partnerships*: Collaborations with brands or influencers for marketing campaigns using AR, generating income from sales commissions.

Costs: What costs are associated with implementing AR?

The costs associated with implementing AR solutions can vary significantly depending on the application's complexity, product type, and technical requirements. These costs may include:

❖ *Software Development*: Creating and programming AR applications requires specialized technical resources. Development costs may include team salaries, costs for AR software technologies, software licenses (e.g., for Unity or ARKit), and testing expenses.

❖ *Necessary Hardware*: Companies may need specific hardware to test and run AR applications, such as high-end smartphones, AR glasses, or VR equipment, depending on the application.

❖ *Content Creation*: Depending on the AR application, significant investments may be required in creating high-quality 3D content. This can include 3D modeling costs, animations, and graphics, especially for premium solutions.

❖ *Marketing and Promotion Costs*: Implementing AR requires promoting the new experience to customers, involving online and offline advertising expenses.

❖ *Maintenance and Updates*: Once the AR application is launched, frequent updates may be needed to adapt to user feedback and technological advancements. These updates can include bug fixes, adding new features, or support for new devices.

❖ *Training and Technical Support*: Companies may need additional training sessions for employees in using and maintaining AR solutions. Ongoing costs for customer support may also exist.

4.2. Different Types of Business Models Based on AR

Currently, the consumer market, including the textile sector, offers a variety of business models that can be adapted to current consumption trends, including sustainability, personalization, and digitalization. Each model can be adjusted to fit consumer needs and preferences, contributing to the business's long-term success.

Among the most recognized are:

❖ *Product-Based Direct Sales Model*: Companies manufacture their textile products, from fabrics to finished items (clothes, bed linens, rugs, etc.). In this model, companies can offer physical products enhanced with AR experiences.

❖ *Experiential Shopping Model*: Stores that use AR to offer customers an interactive experience where they can explore collections through augmented views and interactive presentations. Clothing stores may have tablets or AR installations where customers can scan products to obtain additional information, such as design inspiration, care instructions, or styling combinations, all within an engaging visual experience.

❖ *Interactive Customization Model*: Customers can create their designs for items like t-shirts or clothing through various applications. Using AR to allow customers to customize textile products in real-time lets them visualize the design applied to the garment before purchase. The combination of AR and 3D printing offers customers the ability to create personalized textile items based on an AR model, which can then be printed. This model can include partnerships with customers to create exclusive designs.

❖ *Subscription-Based Model*: Monthly textile product boxes: Customers pay a monthly fee to receive a box with textile items (e.g., clothing, accessories, etc.) selected based on their preferences. Visual details about the products can be accessed by scanning a QR code on the

package or clothing label, allowing users to see how the material behaves under different lighting or from various angles.

❖ *Dropshipping*: Selling without stock: Companies sell textile products without physically holding them. When a customer places an order, the product is shipped directly from the supplier to the customer. AR is used in this business model to inform customers about product quality, maintenance, etc.

❖ *Education and Information-Based Model* (Reconditioning and Recycling Sustainable Textiles): This model involves reusing textile materials to create new products. Companies may collect used clothes and transform them into eco-friendly fashion items. AR in this business model is used to inform and educate customers about textile product sustainability. For example, by using QR codes to provide information on eco-friendly production processes or textile recycling.

❖ *Marketplace-Based E-commerce Platforms*: Marketplace for sellers: Creating an online platform that allows other sellers to list and sell their textile products, earning a commission from sales. Developing online sales platforms that integrate AR allows users to interact with products more dynamically. For example, customers can view textile items against different backgrounds or experiment with how different items match each other.

❖ *Fashion Rental*: Clothing rentals: Providing a platform for renting clothes (e.g., evening dresses, event suits) for special occasions, offering a sustainable alternative to purchasing rare items. Implementing an AR application allows customers to “try on” clothes virtually, giving users the ability to see how the clothes would look on them using a phone camera or specialized device.

❖ *Branding and Influencer Marketing*: Partnerships with influencers: Creating partnerships with fashion influencers to promote textile items and increase brand awareness. An AR campaign allows both influencers and customers to engage in an interactive game featuring products from the collection, thereby creating new interactions and earning rewards or discounts.

❖ *Textile Design Consulting*: Consultancy services: Offering consultancy services for other textile companies in design, marketing, and production, supporting innovation and process improvement. Using AR technology allows designers and producers to visualize textile items in different environments and contexts before production. This can include simulating different colors, textures, and styles on various types of garments.

Benefits of AR/VR in These Business Models

The use of AR/VR technology in the above business models allows customers to “try on” clothes online or see how textile items would look in their environment, such as clothing on their own bodies using the phone camera or a specialized device. Additionally, creating a catalog of textile products using AR offers a more attractive presentation. Customers can scan QR codes to view clothing items in 3D or activate product demonstrations. Applications like "Dressing Room" use smartphone cameras to overlay different garments on the user’s body, providing a simulation of how these clothes would look.

AR can also allow designers and producers to visualize textile items in different environments and contexts before production, including simulating colors, textures, and styles on different articles and environments.

AR-integrated marketing campaigns create captivating experiences for customers. For example, companies can launch interactive games or challenges using AR, involving their products and offering attractive rewards to participants.

Using AR to train employees in retail stores helps them better understand the products and how to interact with customers. It may also include customer support during the buying process, providing useful information about the products.

Implementing AR solutions in physical stores allows customers to explore collections interactively, obtain product information, and see how different textile item combinations would look in real-time.

These AR-based business models transform how customers interact with textile products. By using AR, companies can offer a more interactive, personalized, and well-informed shopping experience.

This innovation not only increases customer satisfaction but also helps drive sales and build brand loyalty in an increasingly competitive market. Implementing these technologies presents an excellent opportunity for textile brands to differentiate themselves and meet the ever-changing needs of consumers.

4.3. Case Studies of Successful Use of Augmented Reality

One of the first companies to integrate Augmented Reality (AR) into the market was **Yellowjacket**, which launched an AR application in 1990 to assist in evaluating construction costs.

However, a more well-known and recognized company for effectively using AR in marketing and sales is **IKEA,** with its IKEA Place app, launched in 2017. This app allows users to place virtual furniture in their homes, significantly impacting the shopping and product interaction experience. The application was developed to work on iOS devices using ARKit, allowing users to virtually integrate various products from IKEA's catalog into their real environment. IKEA has successfully used Augmented Reality to transform not only how customers interact with its products but also to improve the entire shopping experience.

The IKEA Place app is more than just an example of technology use; it demonstrates that innovations can lead to increased customer satisfaction, enhanced sales, and ultimately, a closer relationship between brand and consumers. With the success of this campaign, IKEA has set high standards for other companies across industries to follow, demonstrating how technology can revolutionize traditional business practices.

Other well-known companies that have integrated AR technology into their business models include:

❖ *Puma AR Experience*: Puma created an AR campaign allowing users to interact with its sports shoes through AR games and filters.

❖ *Nike – AR for Personalization*: Nike implemented AR in its stores, enabling customers to virtually customize their shoes. Customers who design their shoes can instantly view the changes, from colors to patterns, before placing an order. This experience improved customer satisfaction and increased sales by encouraging consumers to experiment with the products.

❖ *Adidas - "Create Your Own" App*: Adidas developed an AR app that allows users to design their personalized sneakers. Once the design is complete, consumers can order the product based on their specifications. By integrating AR with 3D, Adidas engages customers in a creative process that enhances brand connection.

❖ *Sephora Virtual Artist*: This app allows users to "try on" cosmetic products virtually using AR. It boosted interaction with the brand and facilitated purchase decisions.

❖ *Zara - AR Project*: Zara launched an AR feature in its stores, allowing customers to scan certain areas to activate interactive video content related to available products. This provides a captivating and contemporary shopping experience, drawing attention to items from the new collection and enabling users to "try on" clothing virtually.

Various fashion brands have begun experimenting with 3D printing in combination with AR. Customers can create unique textile designs, which can then be 3D printed. For example, designer **Anouk Wipprecht** used 3D printing to create garments that activate and transform based on the wearer's health, demonstrating how AR and advanced technologies can merge to offer innovative products.

Examples of Using AR and 3D Printing in Fashion

❖ *Anouk Wipprecht - Smart and Interactive Design*: Designer Anouk Wipprecht is known for using advanced technologies in her clothing designs. Her creations include the "Spider" dress, which uses 3D printing to create a rigid design and also integrates sensors and AR elements. This dress adapts to the wearer's mood and responds to the environment, offering an interactive clothing experience. Through AR, users can visualize how the dress behaves under different lighting and how it interacts with various colors and accessories.

❖ *Iris van Herpen - Haute Couture and Technology*: Iris van Herpen is a brand in high fashion that combines 3D printing technology with traditional design elements. Her creations, such as the dresses from the "A/W 2014-15" collection, incorporate intricate 3D prints and complex structures. Each time a dress is worn, AR can be used to highlight design details, like how lights reflect off the material or how the dress moves while worn.

❖ *Fashion Forward - 3D Printing with AR in Retail*: Some retail stores have started implementing AR solutions that combine 3D printing with real-time customization options. For example, a customer might use an AR app to model a desired garment based on their preferences. Once the design is finalized, it can be sent directly to 3D printing, resulting in a unique garment created exclusively for the customer. This process not only enhances the shopping experience but also allows customers to own unique items tailored to their personal preferences.

❖ *Moar – 3D Printing for Customized Accessories:* The brand Moar offers fashion accessories created through 3D printing, which can be customized using AR applications. Customers can choose different models, colors, and sizes, then see how the products would look with various outfits or in different environments through AR. This model encourages creativity and personalization, significantly impacting consumer choices.

❖ *"Fashion-on-Demand" Philosophy*: An emerging trend is the "fashion-on-demand" concept. Here, customers can use AR applications to explore and design clothing based on 3D images in augmented reality. Once users finalize their designs, these are transformed into real products through 3D printing. This not only minimizes waste but also allows for the creation of unique designs tailored to each customer's specific requirements.

AR-based business models in the textile industry and associated applications, such as 3D printing, significantly transform how consumers interact with products. These case studies demonstrate AR's potential to drive innovation in the textile industry, providing a substantial competitive advantage in today's commercial landscape. This approach not only addresses current market needs but also opens new horizons for creativity and sustainability in fashion, textiles, and the industry as a whole. Brands that adopt these technologies can differentiate themselves in a competitive market, offering consumers unique and personalized experiences.

5. Virtual/Digital Prototyping – Introduction, Glossary

Virtual prototypes, especially in the textile industry, have evolved significantly, driven by the industry's growing interest and that of artisans. Here's an overview of the main advancements made:

❖ *Advanced 3D Modeling*: Designers use 3D modeling software to create digital prototypes that provide a clear representation of the shape and appearance of textile products.

❖ *Material Simulation*: Simulation technologies allow testing of fabric and texture behavior in virtual environments, saving time and resources before physical production.

❖ *Intelligent Algorithms*: Developed algorithms optimize the generation of knitting and weaving patterns, reducing distortions and computational costs.

❖ *Rapid Prototyping*: 3D printing and rapid prototyping allow for creating physical samples from digital models, facilitating the assessment of functionality and aesthetics.

❖ *CAD and CAM Integration*: Integrating CAD (Computer-Aided Design) and CAM (Computer-Aided Manufacturing) software ensures a smooth transition from design to production, enhancing work efficiency.

❖ *Design Validation*: Analysis tools evaluate product performance and validate design choices before market launch.

❖ *Real-Time Collaboration*: Digital platforms enable high-tech collaboration between designers and manufacturers, accelerating product development and communication.

These advancements not only improve the efficiency of the design and production process but also contribute to creating high-quality textile products adapted to market demands.

5.1. Specialized Software for the Textile Industry

Choosing specialized software (in the textile industry and beyond) is crucial, as it can contribute to increased efficiency and cost reduction by automating repetitive tasks. It also allows for rapid and precise prototyping, providing the opportunity to adjust designs quickly based on customer feedback. Moreover, it facilitates better integration of workflows across various departments.

Types of Software:

❖ *CAD Software*: Allows the creation of detailed textile designs, cutting patterns, and sizes (Examples: Gerber AccuMark, Lectra).

❖ *CAM Software*: Automates the cutting and production process, improving efficiency and reducing error risks (Examples: Optitex, CADmax).

❖ *Material Simulation Software*: Helps visualize the physical behavior of materials under various conditions (Examples: 3D Textile, Fabric Simulation Software).

❖ *Project Management Software*: Enables tracking and managing tasks, resources, and time within the production process (Examples: Trello, Asana).

5.2. Virtual/Digital Prototyping for Garments in the Fashion Industry

Virtual/digital prototyping for garments in the fashion industry has become an essential component of the design and product development process. This advanced technology transforms how designers create, test, and present clothing items, offering a series of advantages that improve efficiency and reduce costs associated with traditional prototyping.

One of the most important aspects of virtual prototyping is the ability to create detailed 3D models of clothing items. Using specialized software like **CLO 3D**, **Optitex**, or **Autodesk**, designers can develop precise digital representations of products that reflect not only dimensions and fit but also the textures and colors of materials. This allows designers to visualize garments from various angles and make quick adjustments based on feedback or creative vision. Unlike physical prototypes, which can require considerable time and resources to create, digital models can be generated rapidly, facilitating a more efficient, iterative design process.

Material Simulation plays a crucial role in virtual prototyping. This technology allows designers to test how different types of fabrics behave in virtual conditions, providing them with a better understanding of how materials perform when worn. Simulations can evaluate factors such as drape, flexibility, and durability, helping designers make informed decisions about material selection before moving into production.

Another significant benefit of virtual prototyping is the ability to collaborate efficiently with other members of the design team. Digital platforms enable designers, technicians, and manufacturers to work together in real time. This seamless collaboration is essential in the fashion industry, where the rapid pace of product development requires constant communication and synchronized tasks. Additionally, feedback from clients and stakeholders

can be quickly integrated into the design process, ensuring that the final products meet market needs.

Virtual prototyping offers not only efficiency but also economic benefits. The costs of physical prototypes are often high, involving material purchase, labor, and time. By using virtual prototypes, companies can significantly reduce these costs, as tests and adjustments can be made without investing in physical production for each prototype. Furthermore, the time required to bring a product from concept to market is considerably reduced, allowing brands to respond more quickly to market demands and adapt to emerging trends.

In conclusion, virtual/digital prototyping for garments in the fashion industry represents a crucial innovation that revolutionizes the design and production process. By creating detailed 3D models, simulating materials, facilitating collaboration, and reducing costs, this technology provides designers with a powerful tool to realize their creative vision and deliver high-quality products in a shorter timeframe. Technological innovations in this field continue to evolve, promising to further transform the fashion industry in the future.

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