UTILIZATION OF AUGMENTED REALITY FOR DESIGNING THE LAYOUT OF A MANUFACTURING SYSTEM

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The article presents a methodology for using augmented reality in the design of a manufacturing system layout. It describes the software and hardware tools Autodesk Factory Design Utilities with AutoCAD Architecture, Inventor Professional, and 3ds Max, as well as HoloLens 2 and the workflow from selecting 3D assets, through converting 2D models to 3D representations, to optimizing polygonal geometry for the HoloLens 2 augmented reality headset. An experiment conducted in a real manufacturing environment demonstrated realistic placement of and interaction with machine models such as a lathe, drill press, milling machine, and grinder enabling faster iterations and safe verification of the production layout design. The identified benefits include visual verification, support for training, and flexibility, while the limitations are cost, the need for user training, a limited field of view, and tracking sensitivity. The results confirm that augmented reality is an effective tool for workstation design, simulations, and training.

KEYWORDS

Design, Factory Layout Design, Software, Mixed Reality, HoloLens 2

1 INTRODUCTION

Augmented reality (AR) is defined as a direct or indirect view of the physical real-world environment in real time, enhanced by the addition of computer-generated virtual information [Milgram 1994]. AR is interactive, spatially registered in 3D, and combines real and virtual objects. The reality–virtuality continuum, defined by Paul Milgram and Fumio Kishino, represents a continuous spectrum between the real environment and the virtual environment; within this interval lie augmented reality and augmented virtuality (AV), with AR closer to the real world and AV closer to a purely virtual environment. Augmented reality aims to simplify the user's life by bringing virtual information not only into their immediate surroundings but also into any indirect view of the real-world environment, for example into live video. AR improves the user's perception of and interaction with the real world [Krenicky 2018]. Whereas virtual reality (VR) technology or "virtual environments," as Milgram calls them completely immerses users in a synthetic world without seeing the real world, AR technology enhances the sense of reality in real time by overlaying virtual objects and stimuli onto the real world. Every company operating in an industrial sector involves thousands of operations that must be carried out in accordance with strict regulations. Any mistake leads to huge financial losses, so companies invest significant resources in building competent systems for digitization, testing, and equipment maintenance. Augmented and virtual reality technologies make it possible to simulate any situation, provide necessary information when it is essential, and train people to perform any task without the risk of shutting down entire production or endangering employees' health. Therefore, these technologies are being actively implemented by global companies around the world. For manufacturing plants, it is important to integrate smart technologies into their production systems and keep pace with the industrial revolution [Hajduk 2015]. Modelling manufacturing systems and their subsequent 3D visualization are now indispensable [Kovac 2021, Khosravi 2022]. All large, modern, and advanced companies strive to model and visualize their plants not only to simulate material flow or control production processes, but also as virtual training rooms for new employees or as demonstrations for prospective investors [Demcak 2024]. In today's dynamic environment of manufacturing systems which is constantly changing and adapting to technological innovation efficient and accurate planning is a key element of success. Improving the arrangement of production equipment can have a significant impact not only on productivity and efficiency, but also on the safety, flexibility, and environmental performance of manufacturing processes [Kascak 2019]. One of the most advanced technologies enabling the modelling and optimization of spatial planning and interaction with physical and virtual objects is the augmented reality [Krajcovic 2022]. Augmented reality technologies, which connect elements of the physical and digital worlds, have enormous potential in the field of design. These technologies including augmented reality (AR), virtual reality (VR), and their combination in mixed reality (MR) enable designers, engineers, and planners to visualize and manipulate 3D models and environments in ways that were previously unthinkable [Rudy 2022]. Mixed reality technologies are relatively accessible today, especially in the form of basic AR applications on mobile phones or affordable VR headsets with MR capabilities. However, professional applications still require higher investments in hardware and software. With declining prices and growing competition, MR is expected to become even more accessible and widespread in the future.

2 SOFTWARE TOOLS FOR CREATING THE LAYOUT OF A MANUFACTURING SYSTEM FOR AUGMENTED REALITY

2.1 *Autodesk Factory Design Utilities*

AutoCAD Architecture is a professional architectural design tool that enables efficient creation and editing of projects. It includes features for producing documentation for renovations, designing walls, doors, and windows, and planning rooms. The program offers tools for comparing DWG files, saving projects to the cloud, working with 2D graphics, sharing projects, and importing PDF files. The software contains an extensive library of building elements and both production and non-production equipment, with options for editing in both 2D and 3D views. Users can easily add walls, doors, and roofs; assemblies, sections, and elevation dimensions are generated automatically. The system allows drawings to be neatly organized by floors and visualized in 3D space [Autodesk 2021].

Key features of AutoCAD Architecture:

- Purpose-built architectural objects (walls, doors, windows, roofs, rooms/spaces) with intelligent behaviours,

- Automatic generation of sections, elevations, callouts, and schedules,
- Extensive libraries of building components and equipment; editable in 2D and 3D,
- Room/space planning tools with area calculations and tags,
- DWG file compare, xrefs, and project browser for floor-based drawing organization,
- PDF import and underlay, plus image and point-cloud support,
- Cloud saving/sharing and collaboration workflows,
- 2D drafting + 3D visualization (model views, render previews),
- Annotation tools with styles (dimensions, labels), and standards management
- Interoperability with other Autodesk tools (e.g., Civil 3D, Revit, 3ds Max).

Figure 1. AutoCAD Architecture

2.2 Inventor Professional

Autodesk Inventor Professional enables engineers and designers to combine data from AutoCAD and 3D models into a single digital whole, creating a realistic representation of the final product. Direct compatibility with native DWG files eliminates the need for conversion and minimizes the risk of inaccuracies. Efficient use of the DWG format in Inventor Professional increases competitiveness, improves service quality, and supports the manufacture of innovative products [Autodesk 2021].

Figure 2. Inventor Professional

Key features of Inventor:

- Parametric part modelling and multi-body design,
- Assembly modelling with constraints, joints, and motion,
- 2D drawings from 3D models (dimensions, annotations, BOM, parts lists),
- Any CAD and native DWG interoperability (no conversion required),
- Sheet-metal, frame generator, weldments, and plastic part tools,
- Tube & Pipe and Cable & Harness design environments,
- Built-in simulations (stress/FEA, modal, frame analysis),
- iLogic for rules-based/automated design and configuration,
- Content Centre libraries of standard components,
- Model-based definition (MBD) and tolerance analysis tools,
- Rendering/visualization and explode views/animations,
- Data management and collaboration workflows (Design Views, Shared Views, Vault readiness).

2.3 3DS Max

Autodesk 3ds Max originally 3D Studio and 3D Studio Max is a professional program for creating 3D animations, models, games, and images. It is developed and distributed by Autodesk Media and Entertainment. The software offers professional modelling tools, a flexible plug-in architecture, and runs on Microsoft Windows. It is widely used by video game developers, many televisions commercial studios, and architectural visualization studios. It is also applied in film effects and film previsualization. 3ds Max includes shaders (such as ambient occlusion and subsurface scattering), dynamic simulation, particle systems, radiosity, normal map creation and rendering, global illumination, a customizable user interface, and its own scripting language. The main reason for using this software within the experimental project for creating a production layout in augmented reality was that it enables optimization of 3D models for the HoloLens 2 augmented reality headset.

Figure 3. 3DS MAX

Key features of AutoCAD Architecture:

- Purpose-built architectural objects (walls, doors, windows, roofs, rooms/spaces) with intelligent behaviours,
- Automatic generation of sections, elevations, callouts, and schedules,
- Room/space planning with area calculations, tags, and room finish tools,
- Project Navigator for floor-based drawing organization and xrefs,
- DWG Compare, sheet set management, and standards tools,
- Extensive libraries of building components; editable in 2D and 3D,
- PDF import/underlay, plus images and point clouds,
- 2D drafting and 3D visualization (model views, render previews),
- Annotation styles (dimensions, labels) and display/theme controls,
- Cloud saving/sharing and collaboration; interoperability with other Autodesk tools (e.g., Inventor, Revit, 3ds Max).

3 HARDWARE FOR MIXED REALITY

3.1. Microsoft Hololens 2

It is a standalone wireless augmented reality headset with waveguide optics, advanced hand and eye tracking, spatial audio, and enterprise-grade device management.

Figure 4. Hololens 2

HoloLens 2 is more used in enterprise and professional environments rather than in the consumer segment. It is applied primarily for digital work instructions, procedure verification, and hands-free quality inspection, etc. Detailed technical specifications are provided in Table 1.

Table 1. Hololens 2 technical specifications

Parameter	Value
Type	Standalone mixed reality (MR) headset
Display and optics	Transparent waveguides; “holographic” 2K (3:2) light engines
Main camera	8 MP foto, video 1080p/30 fps
Sensors	1 MP ToF depth, 4× head-tracking cameras, 2× IR eye-tracking cameras, IMU (accelerometer/gyroscope/magnetometer)
Audio	5-microphone array, built-in spatial audio
Processor	Qualcomm Snapdragon 850 + HPU 2.0
Memory	4 GB LPDDR4x
Storage	64 GB UFS 2.1
Connectivity / Ports	Wi-Fi 802.11ac 2×2, Bluetooth 5.0, USB-C (Dual-Role Power)
Battery	~2–3 hours active; on standby for up to ~2 weeks
Weight	~566 g
Operating system	Windows Holographic (optional upgrade to Windows 11)

4 SELECTION OF MANUFACTURING RESOURCES AND THEIR INTEGRATION INTO MIXED REALITY

4.1 Procedure for preparing a model for mixed reality glasses:

In the first step, a 3D model needs to be obtained. The digital library (Fig. 5) within Autodesk Factory Design Utilities helps with this and cooperates with other Autodesk software tools.

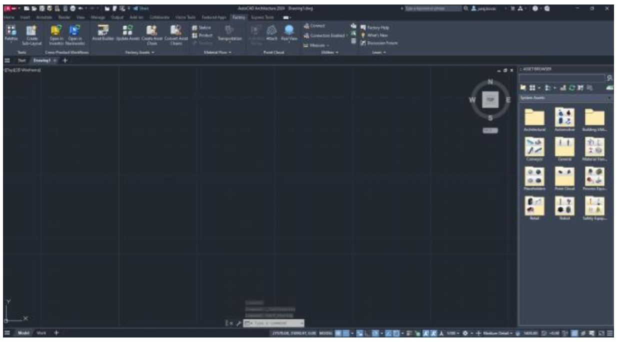

Figure 5. Digital Library (Utilities)

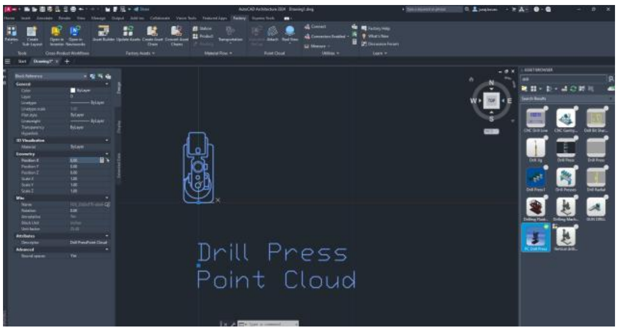

Figure 6. Entering the starting position of the machine in the coordinate system

In the experimental project, AutoCAD Architecture, Inventor Professional, and 3ds Max were also used to optimize files for the HoloLens 2 augmented reality glasses. After launching AutoCAD Architecture, you need to open the library of manufacturing equipment and select a suitable production machine.

Next, select and download the manufacturing machine from the cloud, set its initial position at the origin of the coordinate system (as shown in Fig. 6), and place the machine onto the workspace in the 2D view. After placing the manufacturing equipment in AutoCAD Architecture, the 2D model needs to be converted to a 3D view using Inventor Professional. In AutoCAD Architecture, this function is available directly on the top toolbar, as shown in Fig. 7.

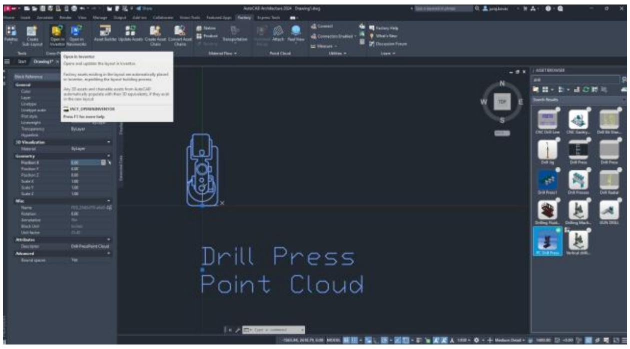

Figure 7. Convert the 2D model to a 3D view

Subsequently, the manufacturing equipment is displayed in Inventor Professional as a three-dimensional model (Fig. 8).

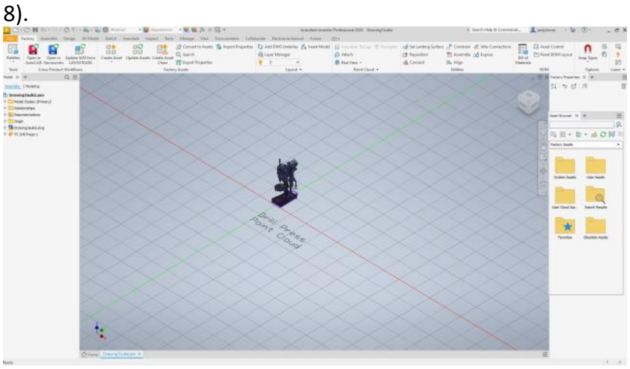

Figure 8. Three-dimensional model of the manufacturing equipment

In the next step, the machine model needs to be saved in the OBJ format (Wavefront OBJ text format for exchanging polygonal 3D models) using the “Export file to CAD format” function, as shown in Fig. 9.

Subsequently, we can open the file in 3ds Max, where the polygon count of the machine’s 3D model must be adjusted. In 3ds Max, use the Calculate function to enable polygon editing. After the calculation, you can use the Vertex function to change the number of polygons as a percentage. To make the model usable in HoloLens 2 mixed reality glasses, reduce its polygon count so that it is at most 10,000. The same procedure was applied to every manufacturing equipment model used in the experiment, as illustrated with the drill press.

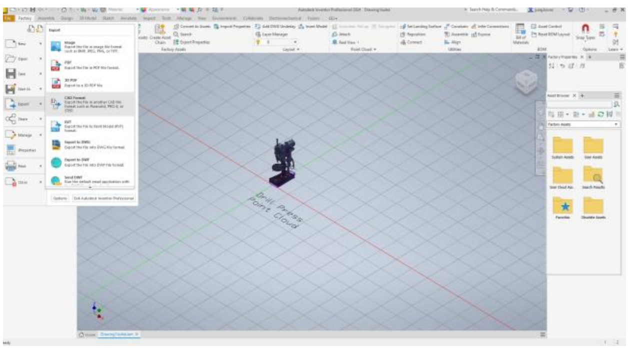

Figure 9. Exporting the file to OBJ format

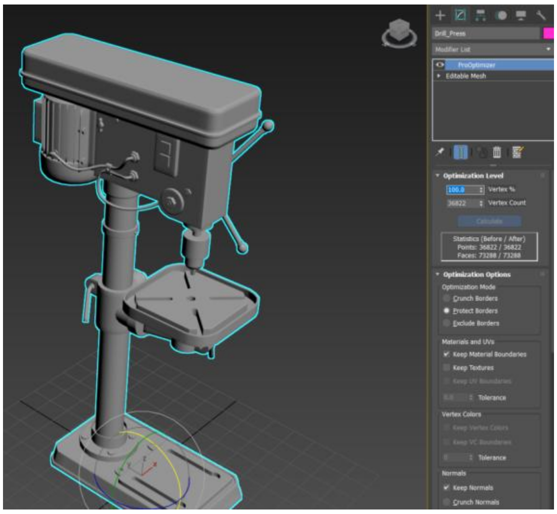

Figure 10. Adjusting polygon count for mixed reality [Shevchenko 2025]

The optimized machine model must be saved again in the OBJ format to display the model in HoloLens 2 glasses. We upload the machine models to the headset via a USB cable. After putting on HoloLens 2, extend your wrist in front of you (Fig. 11) and press the Windows logo that appears with your other hand.

Figure 11. Initial startup of HoloLens 2 [Shevchenko 2025]

The user's main menu appears, where we can import the machine models. In the next step, we need to upload them to the headset's internal library, where they will be ready for display in augmented reality.

Figure 11. Importing model into the headset library [Shevchenko 2025]

5 EXPERIMENTAL VERIFICATION OF AUGMENTED REALITY IN A REAL MANUFACTURING ENVIRONMENT

This chapter of the publication presents a visual demonstration of augmented reality capabilities and compares what the user sees through the headset with the real manufacturing environment. It also summarizes the experiences to date specifically, the advantages of augmented reality for designing a factory layout in a real-world setting. The experiment served as a visual showcase of augmented reality in an actual production environment. The goal was to show how augmented reality can display 3D machine models in real space using specialized glasses, as well as the difference between what a user sees through the glasses and what it looks like to an observer without them.

The demonstration took place in a real space, where realistic 3D models of manufacturing machines were displayed through the glasses. Images from the user's perspective showed detailed visualizations of these machines placed in the room (lathe, drill press, milling machine, and grinder). These models were precisely integrated into the real environment, and the user could interact with them using gestures. A side view reveals that the user does not actually see physical objects but rather responds to digital elements appearing in their field of view. With hand gestures, the user controls or triggers various functions such as selecting machines, moving within the space, or zooming in on specific parts as shown in the series of Fig. 12.

See without mixed reality glasses	Experience mixed reality through Hololens 2 glasses
	
	
	
	
	

Figure 12. Visual demonstration of design in mixed reality [Shevchenko 2025]

Summary of the experience of working in augmented reality:

- Enables realistic simulation of a manufacturing environment without the need for physical equipment,
- Significantly supports the educational process visual and interactive learning,
- Flexibility in displaying various machines and their parts, which would otherwise require large investments in equipment,
- Requires specific hardware (e.g., HoloLens), which is costly and requires training,
- Possible issues with spatial tracking in poor lighting or unsuitable environments,
- The limited field of view in MR glasses can affect the user experience.

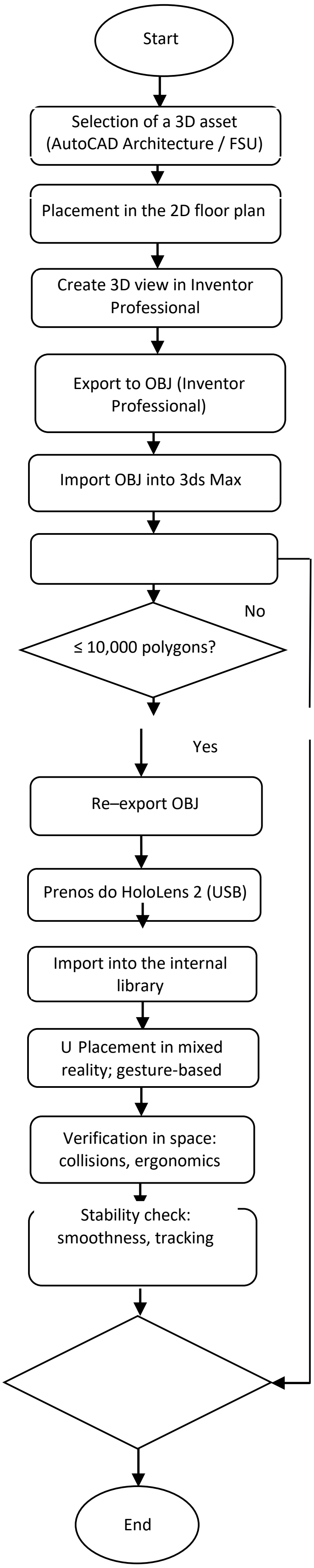

Figure 13. Flowchart of the process of creating a digital model for augmented reality

The experiment with augmented reality showed that it is an exceptionally effective tool for visualizing virtual machines under real manufacturing conditions. Despite certain technical challenges, augmented reality has great potential for future industrial applications, especially in training, simulations, and workstation design.

6 CONCLUSIONS

The use of AR in manufacturing plants ranks among advantageous and currently very relevant practices in industrial engineering. Each year, more industrial companies adopt AR technology to increase efficiency in production processes. The possibilities are growing, especially in assembly, maintenance, and quality control. Implementing this technology brings positive changes to the manufacturing industry [Karrach 2020]. It highlights not only economic indicators but also the increased attractiveness of job positions, which are drawing ever greater interest from applicants.

This paper confirms that deploying augmented reality with HoloLens 2 for factory layout design is technically and procedurally feasible and brings practical benefits. The described workflow AutoCAD Architecture, Inventor Professional (OBJ export), 3ds Max (geometry reduction to ≤ 10,000 polygons), and deployment to AR enables transferring 2D designs into an interactive 3D environment and quickly validating variants directly in real space. The experimental demonstration confirmed improved spatial understanding, support for training, and safe testing without physical interventions. At the same time, it revealed limitations in the form of hardware cost, the need for training, a limited field of view, and sensitivity to tracking conditions and lighting. For practice, it is recommended to keep model complexity low, build a consistent library of 3D assets, and prepare users to work in mixed and augmented reality. On this basis, such technology has the greatest benefit in simulations and the design of workplace layouts before their physical implementation.

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