



Extended Reality in Industry4.0 (ERI)

Lecture 17: Digital Twin and ML in XR

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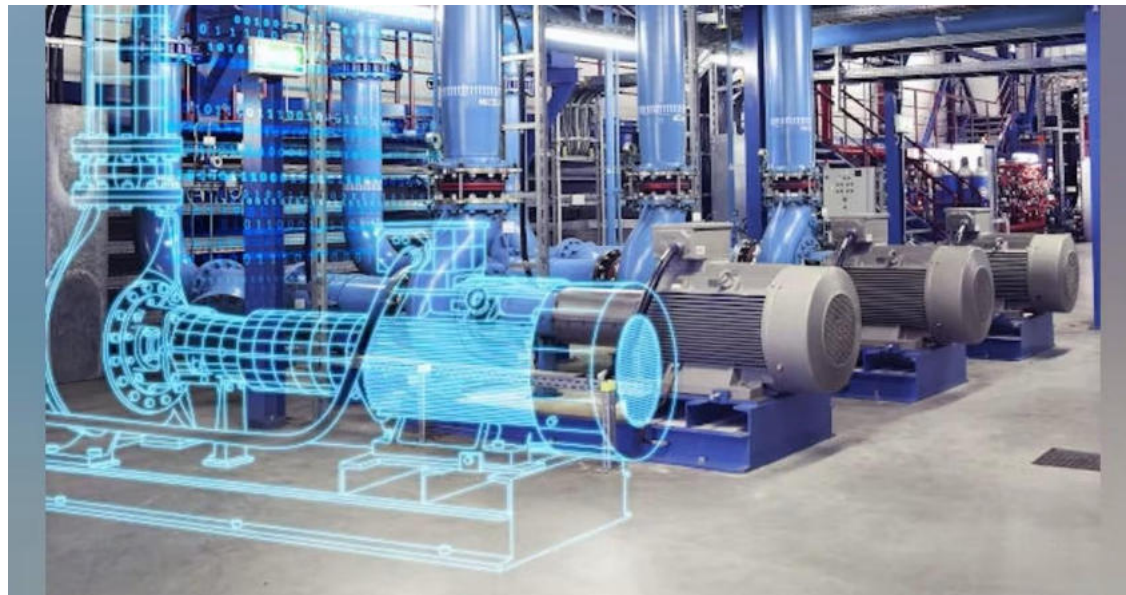
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Introduction to Digital Twin

- The intelligent factories employ sensors to monitor various machines within the facility by implementing Industry 4.0 principles.
- By monitoring production data, it is possible to enhance manufacturing accuracy and prevent key components from malfunctioning.
- Digital Twin (DT) is a rapidly developing technology aimed at enhancing the connection between physical and virtual spaces to improve the performance of physical spaces.

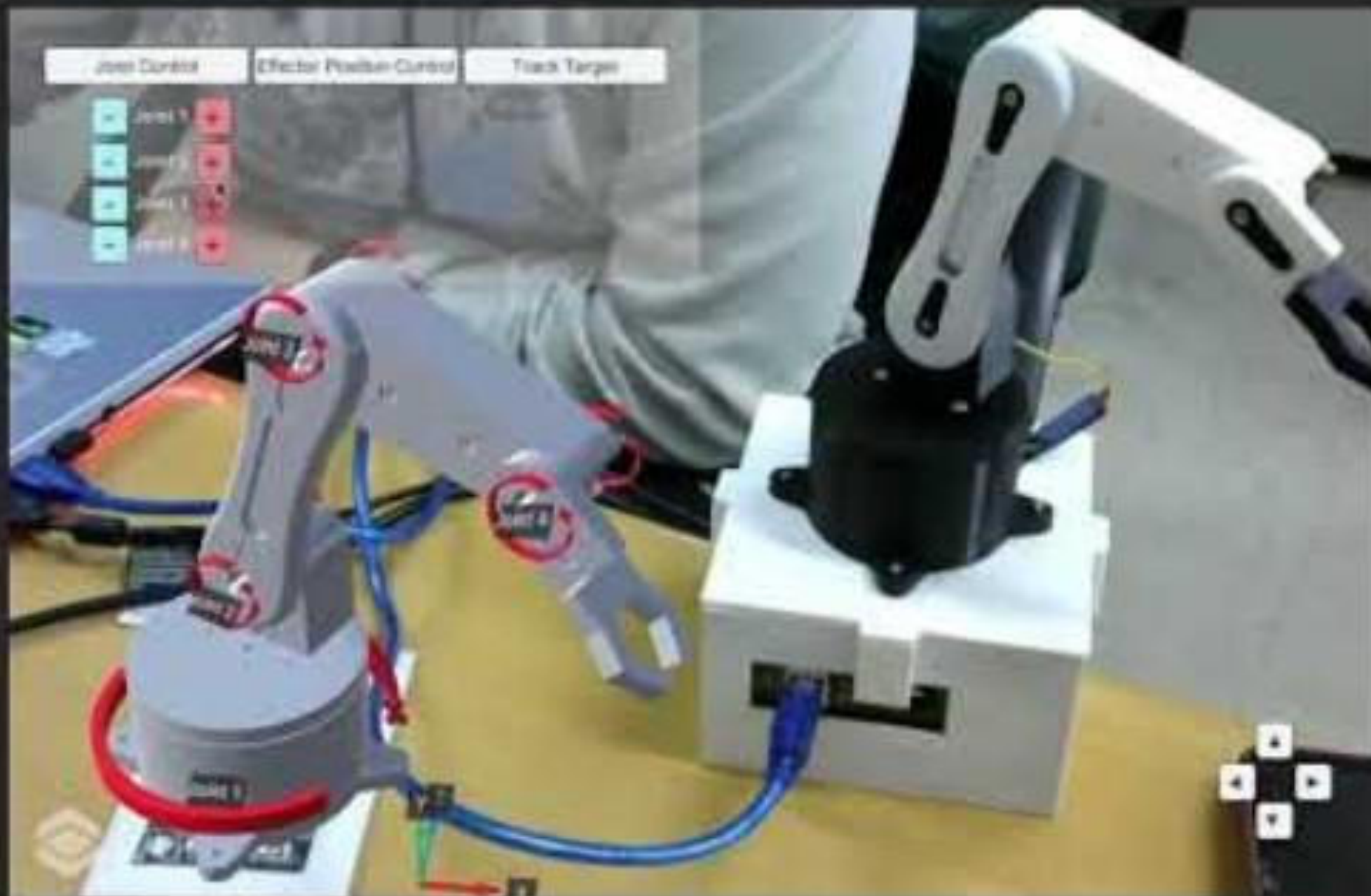
Introduction to Digital Twin

- A DT comprises a virtual model that integrates and linked to a physical entity through the Internet of Things (IoT), allowing for a bidirectional information flow between the physical entity and its virtual counterpart.
- The virtual space offers services like predictions, simulations and optimizations with the latest information .



Introduction to Digital Twin

- The term DT is frequently misused and often confused with **digital models** or **digital shadows**.
- All three terms differ from each other in the degree of data exchange or integration.
- In **digital model**, the data flow between the physical and virtual space is entirely manual.
- In **digital shadow**, there is an automated unidirectional data flow from the physical object to digital object.
- A true **digital twin** emerges only when an automated bidirectional data flow connects the physical and virtual spaces.

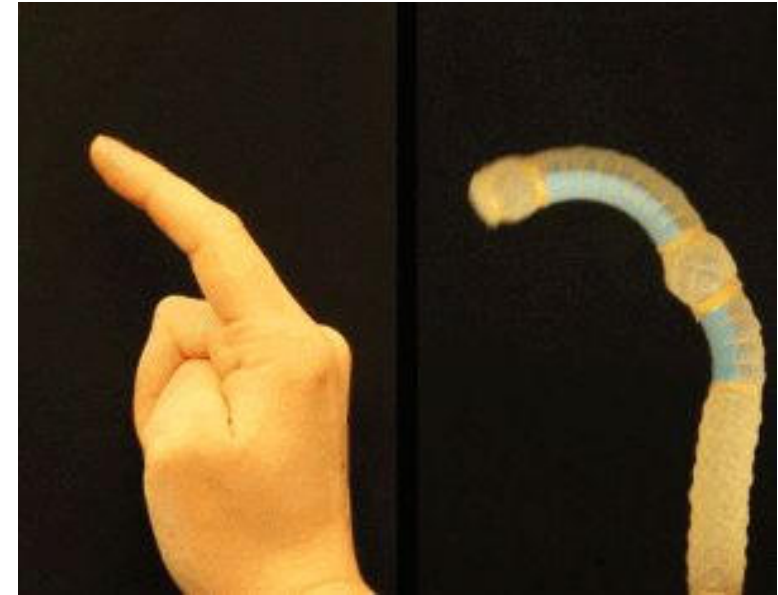


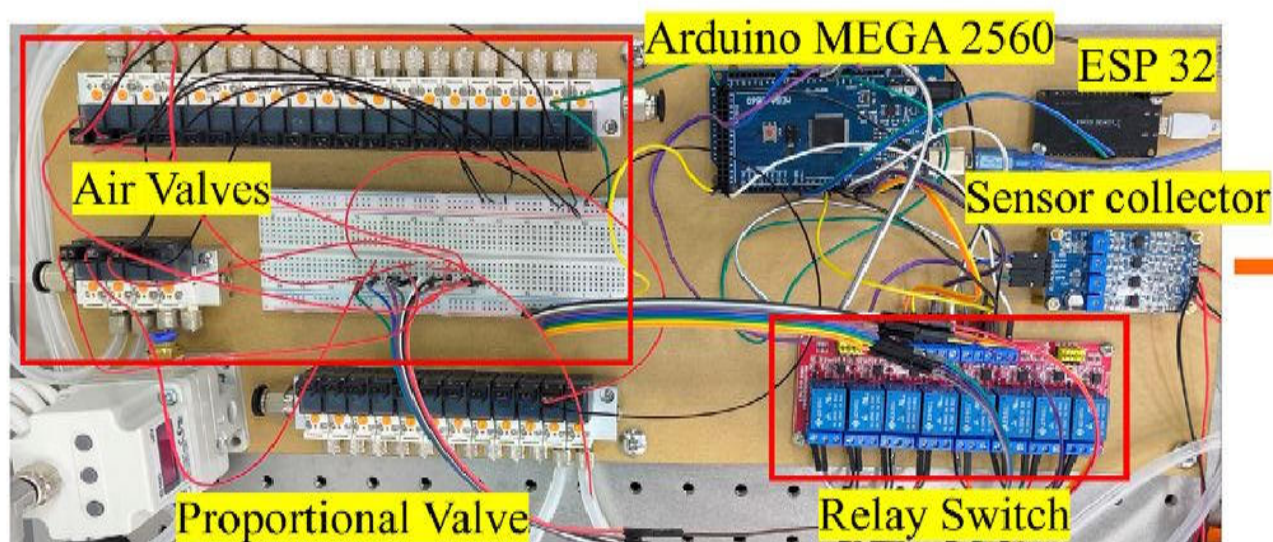
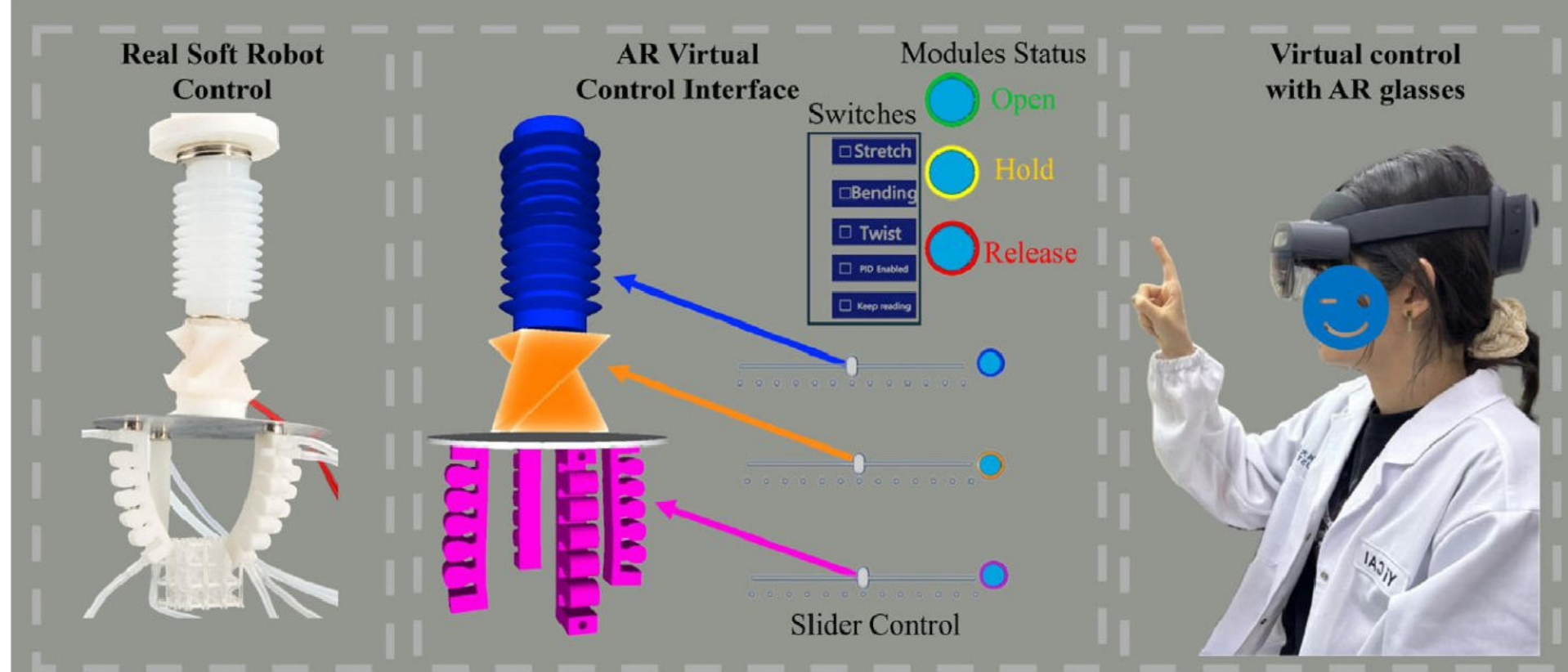
Applications of DT

- Product quality
- Predictive maintenance
- Performance improvement
- DT for real time data analysis to predict the failure of a machine
- Optimizing warehouse design
- Improving personalized care
- Real-time process simulation

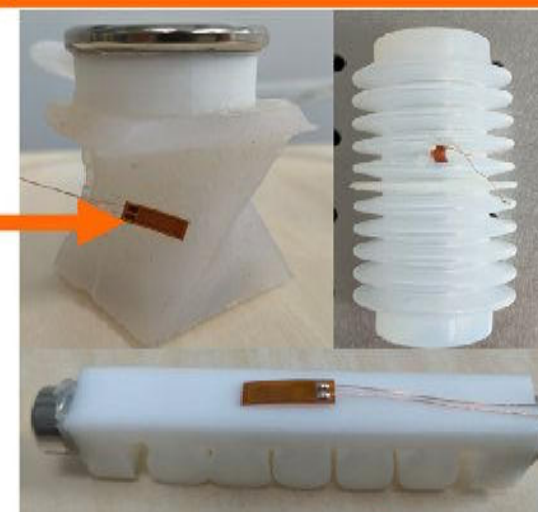
AR-enabled DT for reconfigurable soft robots

- Soft robots are flexible devices that execute programmable complex motions controlled by external stimuli.
- The existing visualization and simulation tools struggle to adequately represent the complex deformation behavior of soft robots.
- Researchers developed a DT system for reconfigurable soft robots set within AR environment.
- The aims of this work are to accurately depict 3D soft deformations of robots and provide an intuitive interface for simulation.

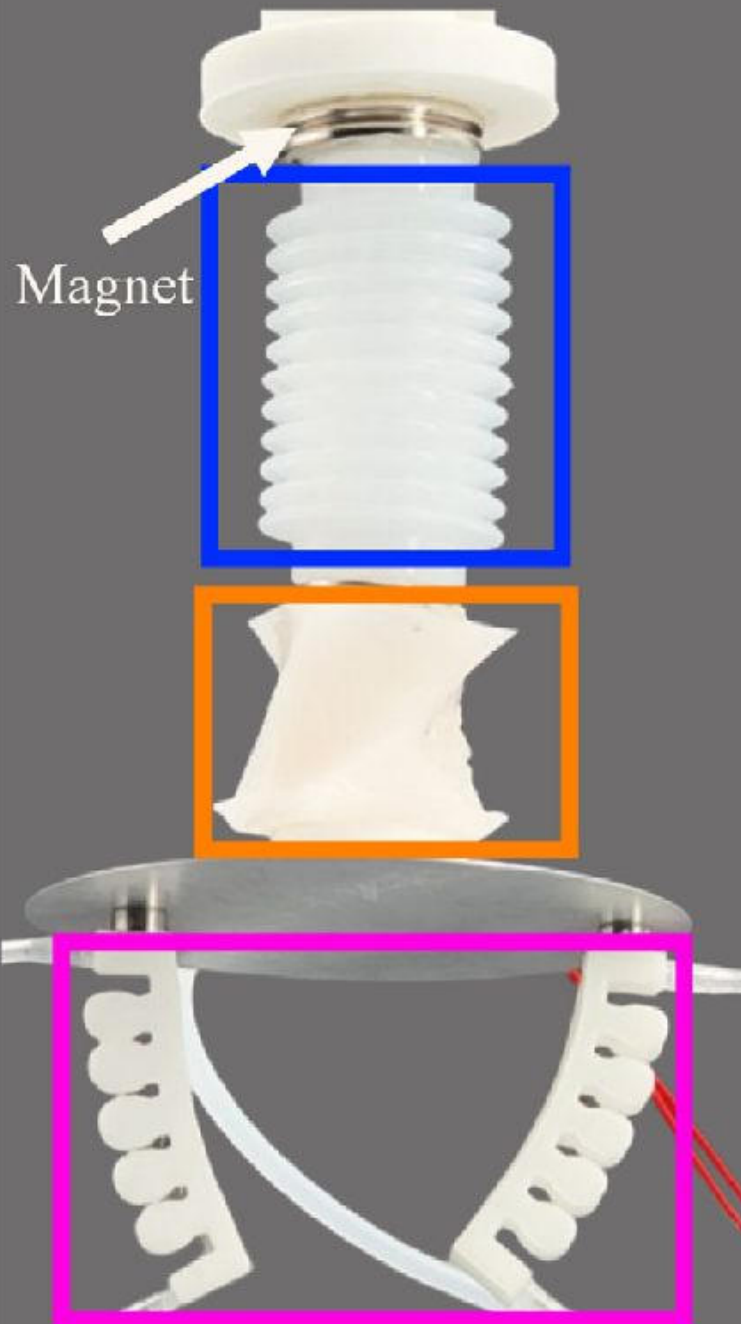




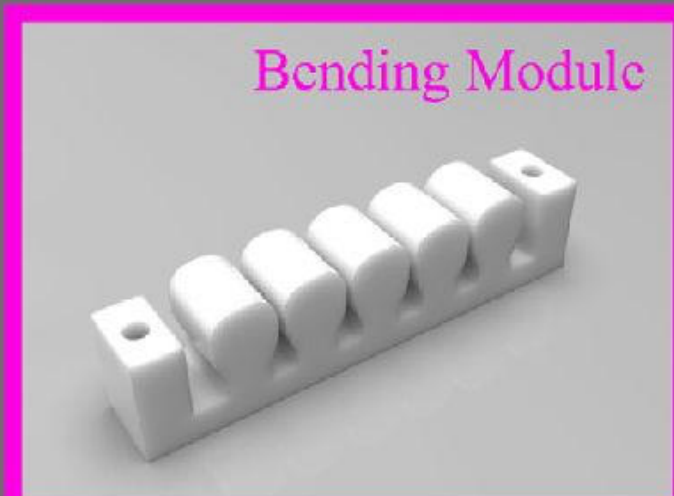
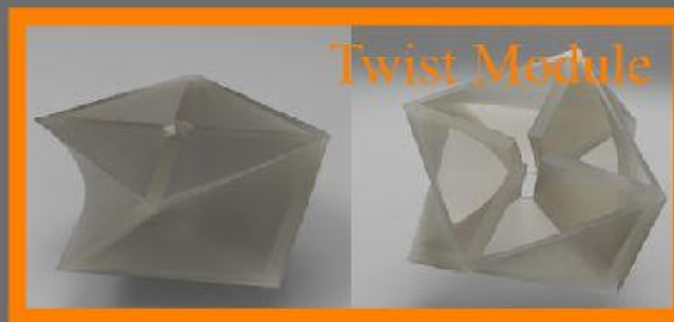
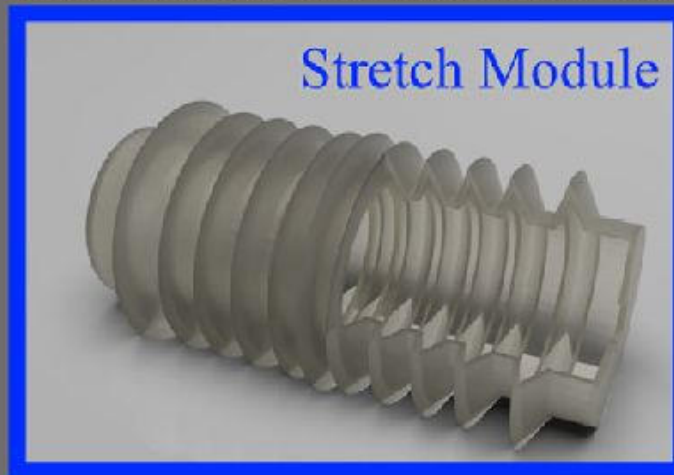
Three basic soft modules



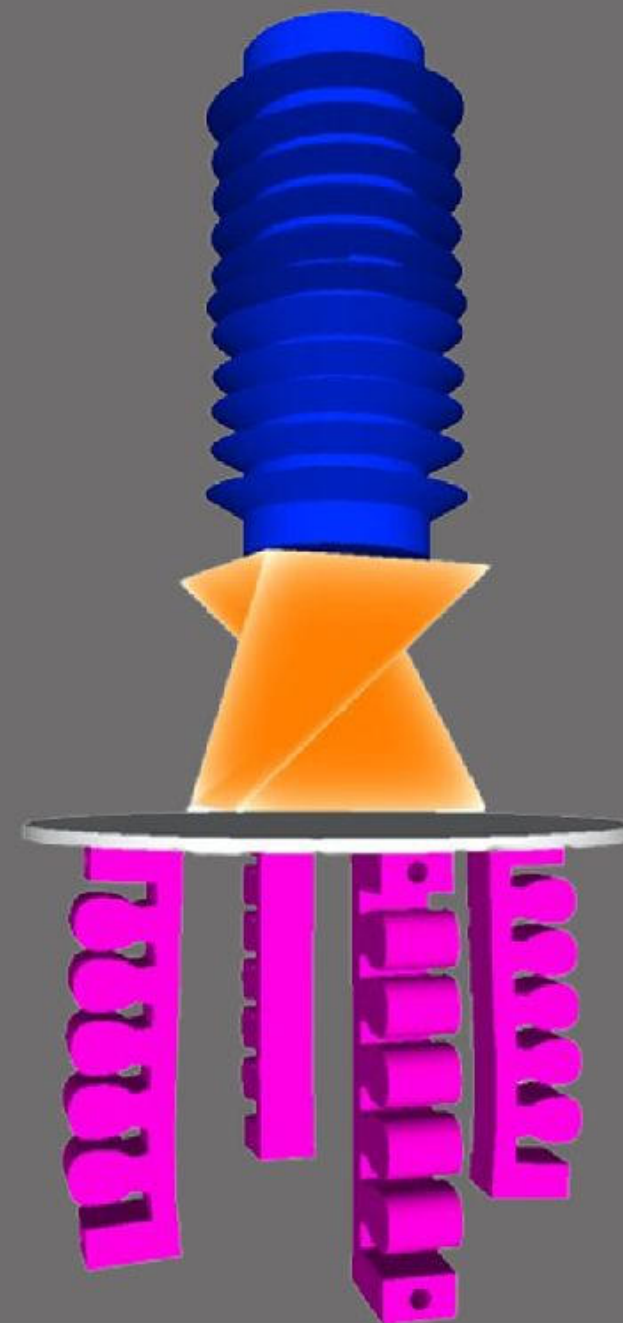
Real Soft Robot



Soft Robot Modules Model



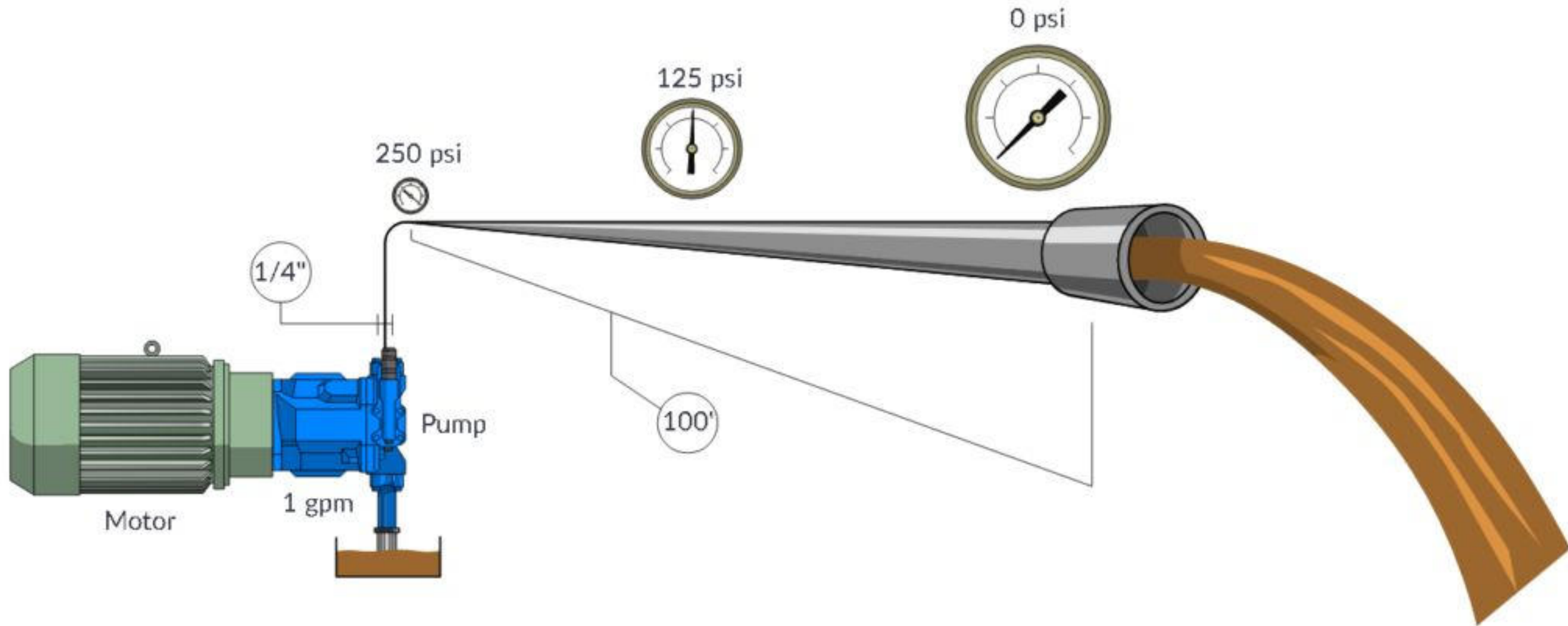
Digital Twin Vision



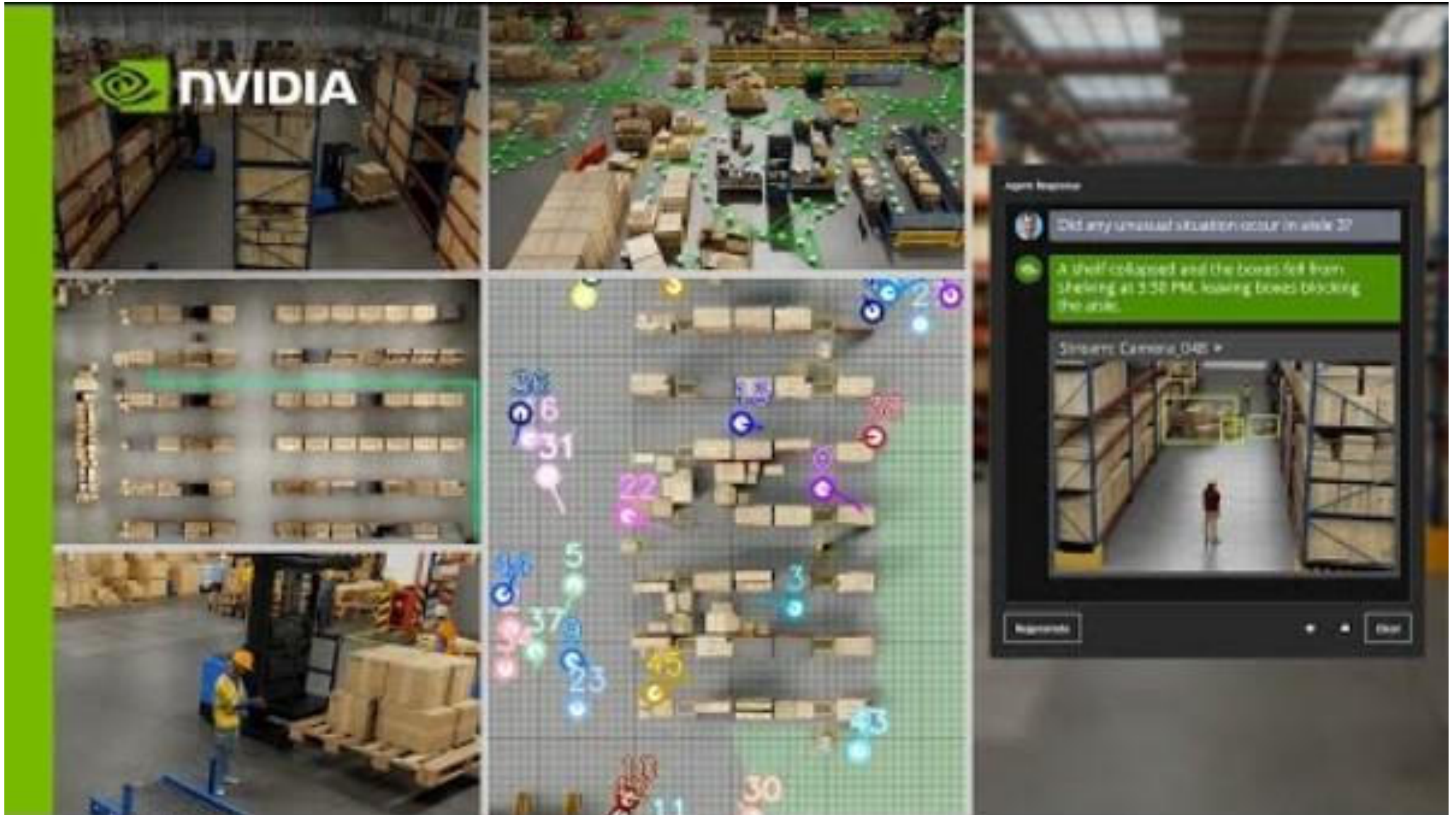
Applications of DT



Digital twin of a hydraulic pump



DT and AI in Industry 4.0



Machine learning (ML) in XR

- Machine learning is a subfield of artificial intelligence (AI) or an application of AI that allows machines to extract knowledge from data and learn from it autonomously.
- While AI is the broader concept of enabling a machine or system to sense, reason, act or adapt like a human and imitate intelligent human behavior.

ML applications

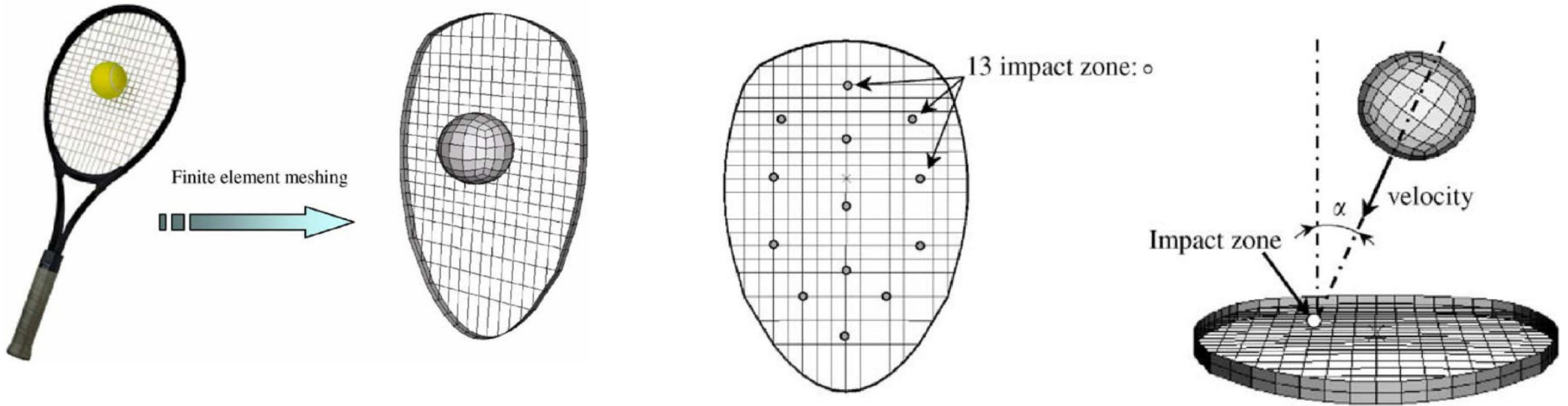
- Predictions
- Classifications
- Speech recognition
- Image recognition

ML in XR

Machine learning can be used in XR environment for various applications including:

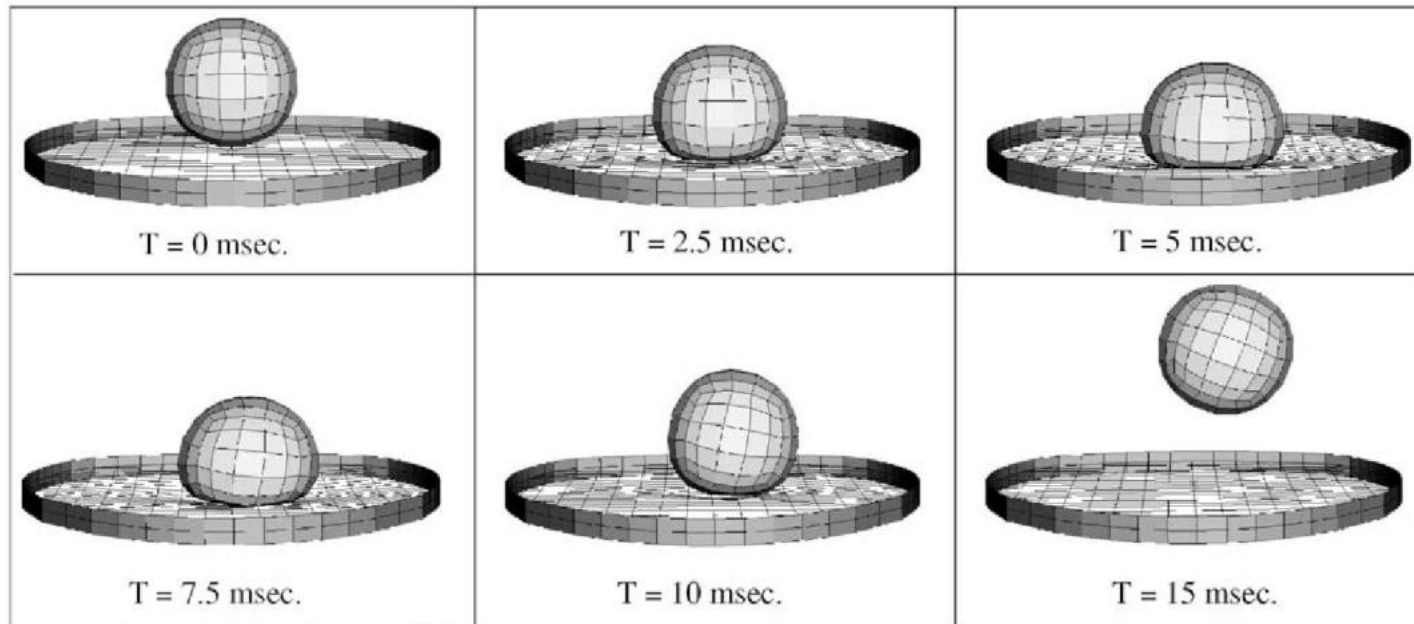
- structural analysis results predictions
- Voice command identification
- gesture recognition
- posture recognition
- skill evaluation
- therapy recommendation for different patients.

ML in VR for deformation prediction of complex structure

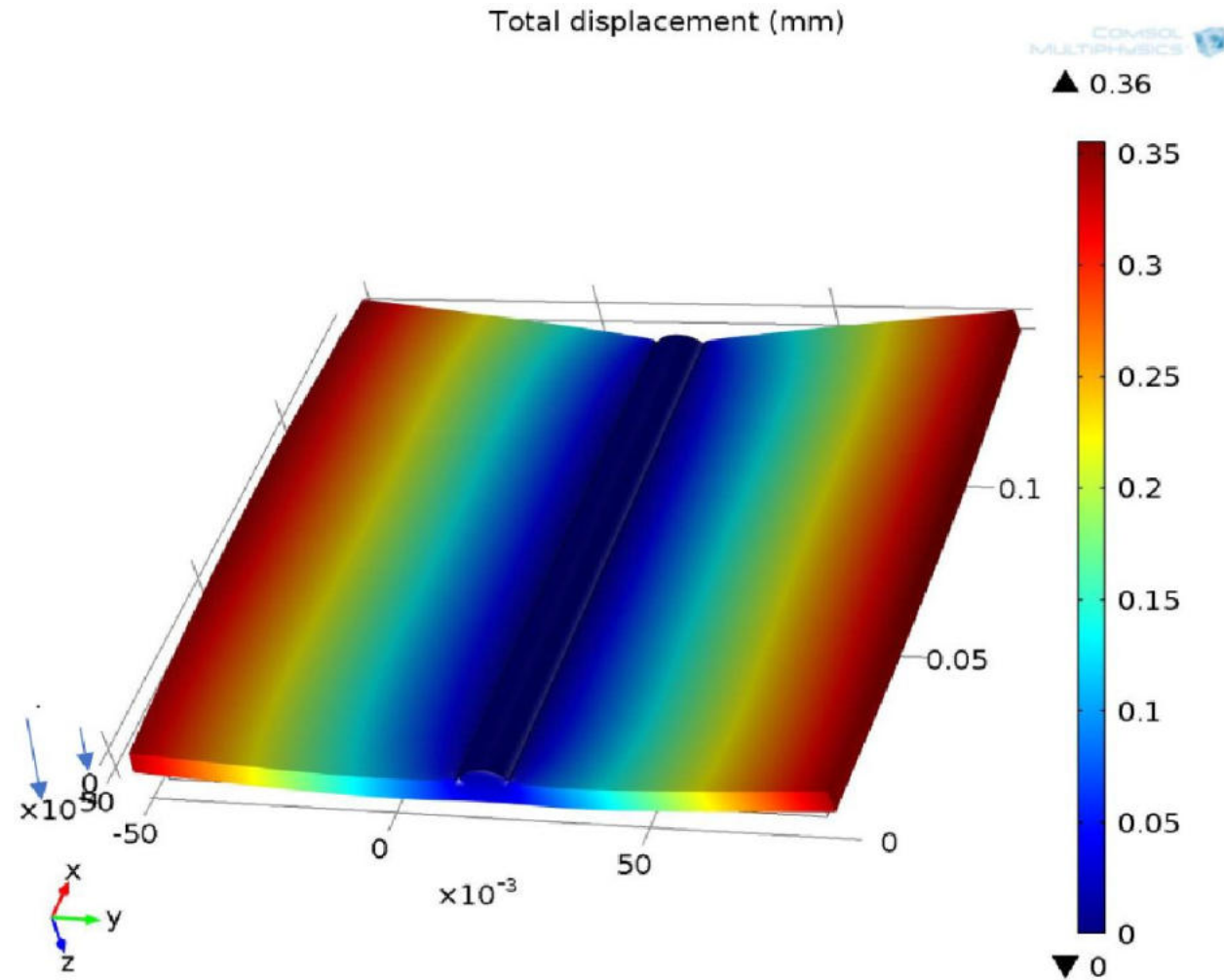


ML in VR for deformation prediction of complex structure

- Force feedback devices are used in VR to produce a tactile sensation on the user immersed in a virtual environment.
- The glove must therefore be capable, in the absence of a real object, of recreating the forces applied by the object on the human hand with the same intensity and the same direction.



Finite Element Analysis results in MR



Welding simulation in FEM software (COMSOL) for deformation analysis

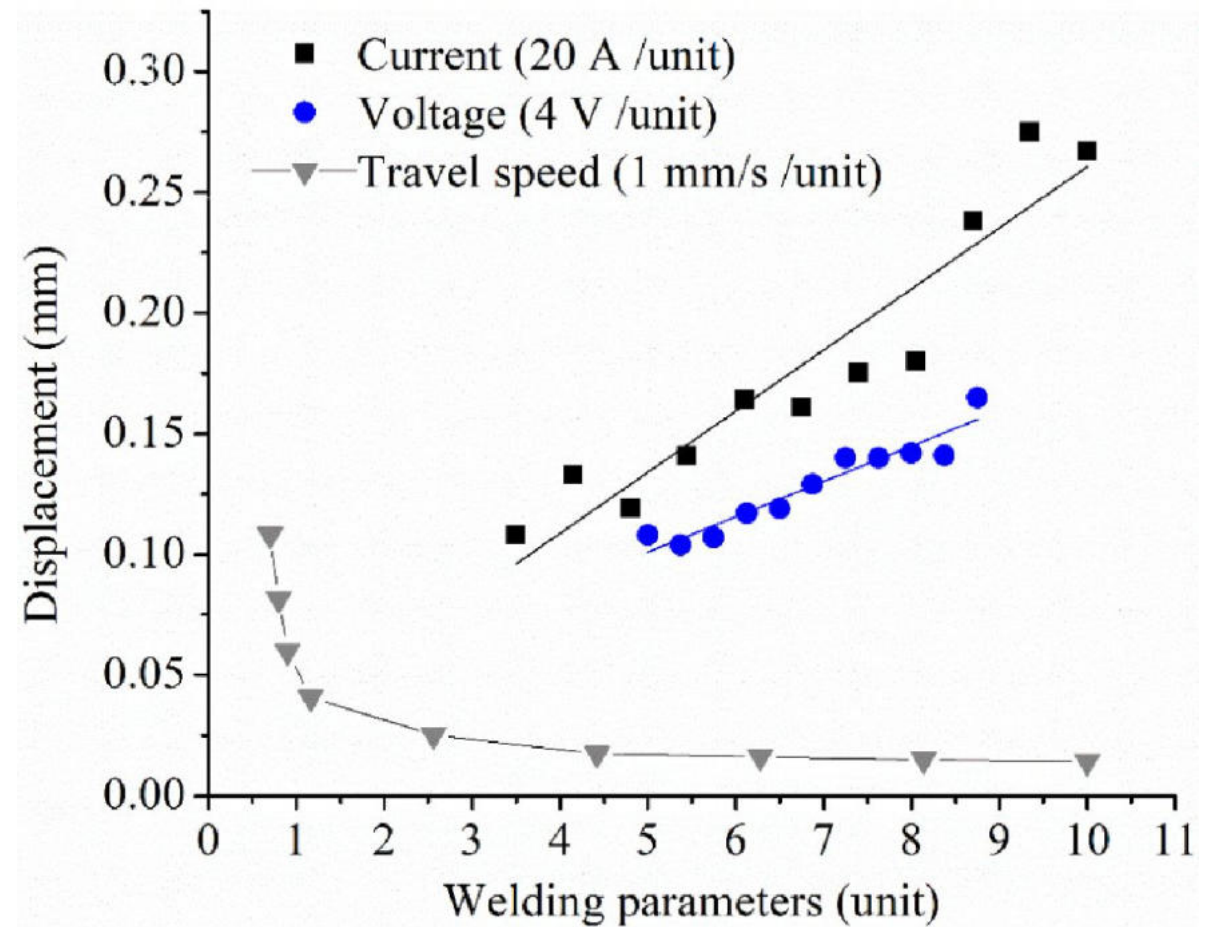
Finite Element Analysis results in MR

Welding simulation for deformation analysis.

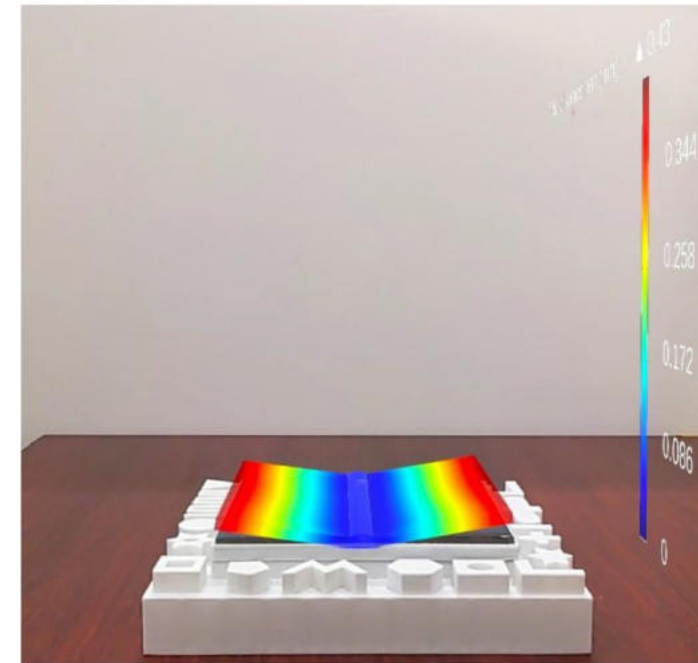
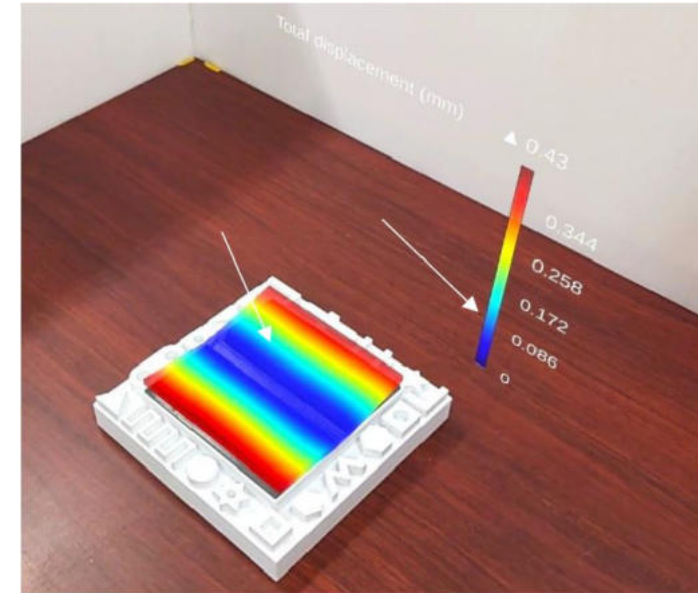
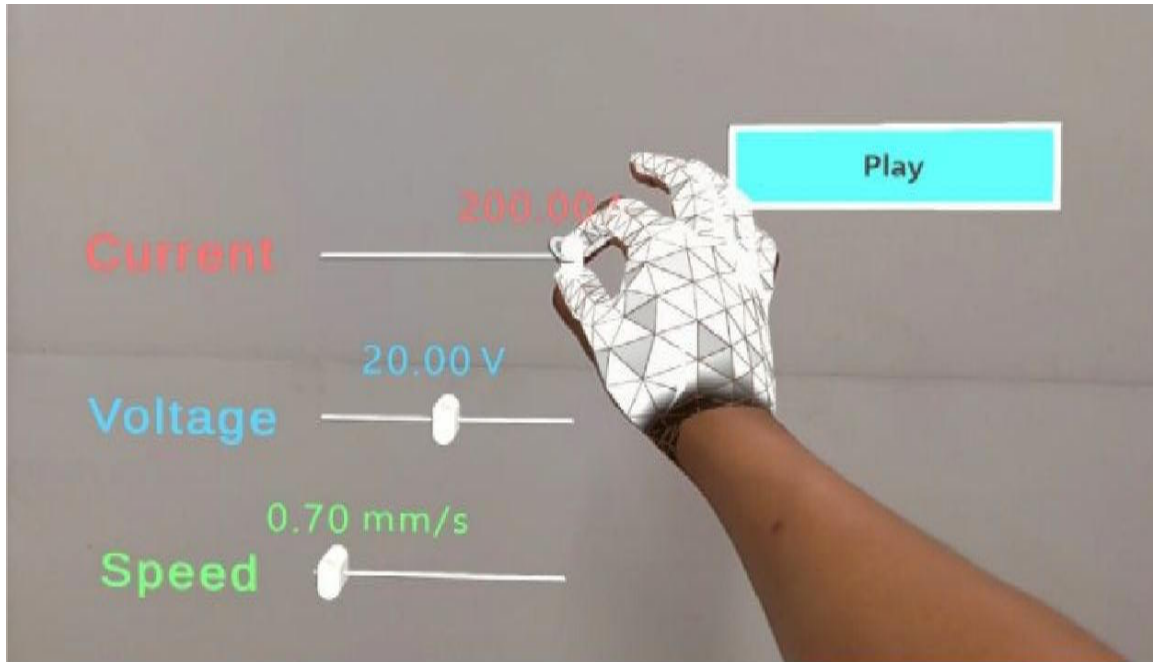
Training dataset:

Input Variables: Current, voltage and speed

Output variable: Displacement



Finite Element Analysis results in MR



ML in XR

- The verbal communication between the user and the XR system can be possible with speech recognition and speech generation methods.

Applications:

1. Virtual reality-based lectures
2. Extended reality-based training and guidance systems
3. Virtual therapy

ML in XR

- Natural language processing (NLP) refers to various techniques that help computers interpret the meaning and intention behind human words. It can analyze grammar, identify keywords, sentiments, and sarcasm. For example, summarizing news articles or analyzing customer reviews.
- Whereas large language models (LLMs) are trained on vast amount of text data to build their own internal understanding of the language itself. Besides understanding human words, it can predict what might be said next. For example, ChatGPT converses like a person.
- LLM can be used for verbal communication between user and XR interface.