doi: 10.1038/s43586-023-00208-z; Article citation ID: 2023 3:15 For the Primer, visit doi: 10.1038/s43586-023-00198-y

PrimeView

Extended reality for biomedicine

Extended reality (XR) involves a group of methods that immerse users in a 3D or 4D environment, including virtual reality (VR), augmented reality (AR) and mixed reality (MR). XR is used in entertainment and education, and its application to biomedicine has the potential to enhance fundamental and translational research.

Experimentation

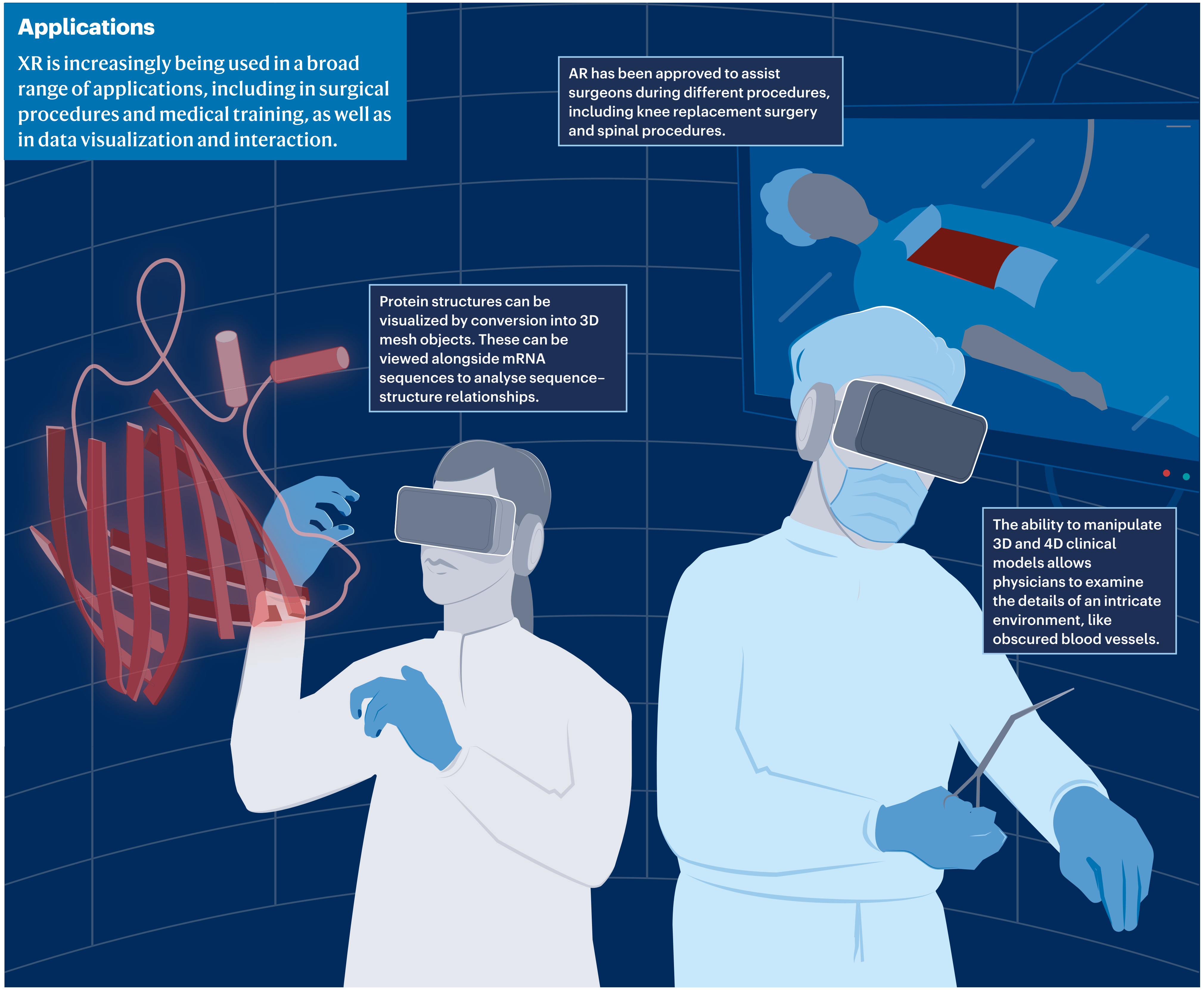
Immersion and interaction in XR requires fundamental hardware components including display, optical lenses, sensors and computational processors. Immersion quality of the head-mounted display (HMD) is mostly dependent on visual display and optical lenses, which determine the field of view (FOV) and angular resolution. Sensors determine input and output stimuli for enhanced immersion and interaction within the XR environment. Electromagnetic, optic and haptic sensors are frequently used in surgical applications. There are a number of biomedically related XR platforms and software that have been developed for interactive visualization of biomedical images, medical education and training.

Results

Analysis of real-world data, like multidimensional imaging and macromolecular structures, is enhanced by the immersive aspects of XR. 3D XR models of imaging data are created from images that are stored as data volumes, followed by visualization through point cloud rendering, surface rendering or volume rendering, depending on the input data. Point cloud data are acquired through any imaging modality, while surface rendering is used for datasets containing gross structures, like those generated from contrast computed tomography. Volume rendering uses the entire imaging volume, bypassing image preprocessing, and is suitable for datasets where segmentation or labelling is difficult. Allowing the user to interact with the virtual environment is key in the use of XR in biomedicine. Motion tracking by sensors either in the HMD or in stationary locations in the environment enable the technology to locate the user in real time in relation to virtual objects. Haptic interaction allows users to manipulate virtual objects and is often accomplished using gloves and teleoperation controllers.

Applications

XR is increasingly being used in a broad range of applications, including in surgical procedures and medical training, as well as in data visualization and interaction.



Reproducibility and data deposition

As XR hardware and software improve, reproducibility remains an unmet need for the design, implementation and assessment of XR systems. Guidelines exist for different XR systems released by commercial organizations. The IEEE are generating standards in various areas of work, ranging from device taxonomy to immersive user interface, file types and safety. While there are many data repositories for 2D objects like images and videos, few exist to store collections of 3D data. Regulations and policies around user privacy, data security and ethical concerns still need to be defined.

Limitations and optimizations

The effectiveness of XR in medical education and training needs to be further investigated. Analyses in surgical settings have found moderate or no improvement when using XR over freehand surgery. Causes are multifaceted, including XR platforms being distracting and issues with software and reproducibility. Immersion is crucial to the performance of XR in biomedical applications, and the trade-off between FOV, resolution and HMD weight is a major challenge. Clinical applications require powerful computational capabilities, which is limited in the more portable XR hardware.

Outlook

Compared with conventional methods, XR provides immersive and interactive contexts to biomedical data analysis. Reduced lag time and resolution with 5G and mobile edge computing will improve computational ability of untethered XR by providing increased transmission efficiency and reduced motion sickness. Technical development of multi-sensory engagement will further enhance the immersive experience.

Written by Dominique Morneau; designed by Alex Whitworth