Review of state of the art in MR for design (Unstructured)

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Date: 15 June 2022

NOTE: See also the slides in the PDF presentation

(Kim et al. 2019) compare multi-touch interactions and hand gesture interaction for AR headsets. And conclude that hand gesture-based interaction can be more intuitive and useful. Furthermore, hand gestures scored higher for 3D manipulation while both multitouch interaction and hand gestures were on par for selection tasks.

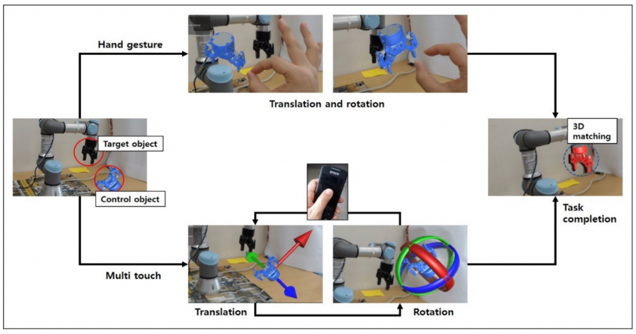
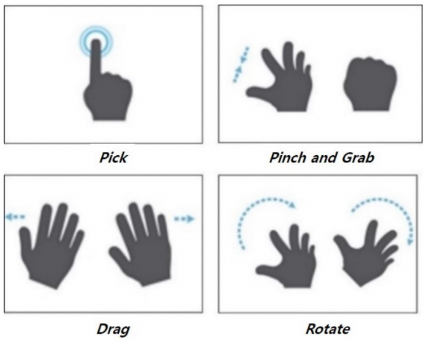
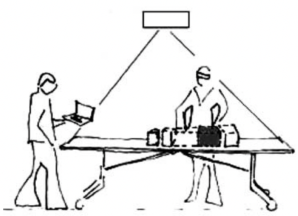


Figure 14. 3D (three-dimensional) matching task between a virtual control object and a physical target object; the gripper of the UR3 robot is used for 3D matching.



(Sandor and Klinker 2005)present a framework that is a mix of modeling-only and presentation-only modes. Users model the design as a scaled-down object on a table and there is a single-view presentation on a screen for all users. However, our focus is different, as we aim to merge the presentation and editing into all view modes instead of strictly separating editing from representation. Their system, preceding today's integrated devices, is hardware heavy, with multiple custom developments. Today you can achieve this on a single headset (Hololens) and ready-made libraries (MRTK). Furthermore, their system is only for 3D modeling, no layouting.



(a) Conceptual drawing of the setup (courtesy of Manja Kurzak)

(b) Tangible objects for modelling and visualization: sun and wall

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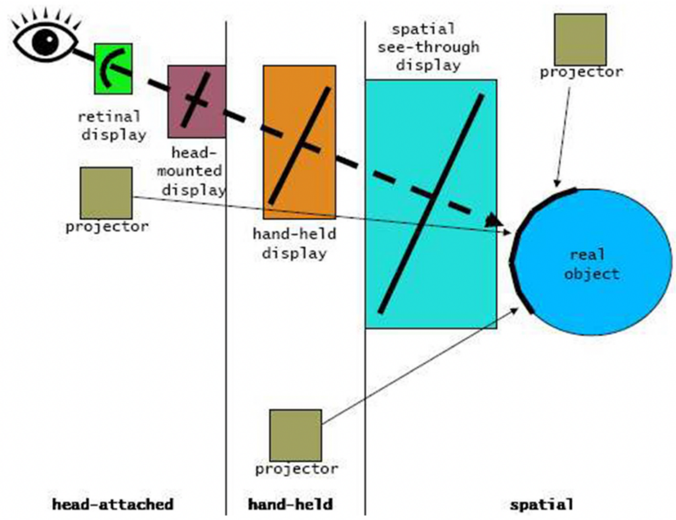
(Giunta et al. 2018)a review of AR for design, even though from 2018, latest references is 2013. They site a good overview diagram of the various AR/VR devices - head-attached, hand-held and spatial.

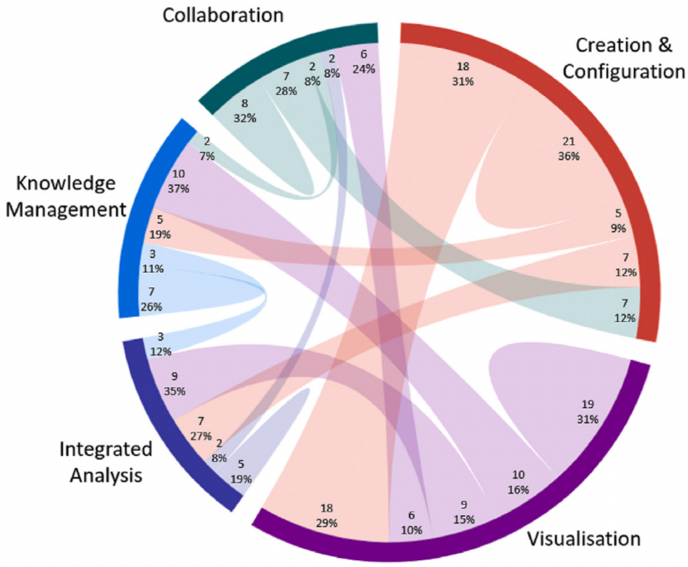


(Kent, Snider, and Hicks 2021)a very good review. Presents a table with physical-to-virtual and virtual-to-physical domain transitions.

Table 3. Inter-domain characteristics, domain transition options and sync speed

Component	Inter-Domain Characteristics	Physical ->Virtual Domain transition options	Sync Speed	Virtual ->Physical Domain transition options	Sync Speed
Physical Prototype	Image Video 3D model Textured model Rigged model CAD reflection Digital Twin Local Position Relative Position Global Position	3D modelling CAD tools Photogrammetry Computer vision Camera Intrinsic Sensors Extrinsic Sensors Fiducial markers Inertial sensors GPS	Slow Slow Medium Fast Fast Fast Fast Fast Fast Fast	Human actuation Conventional Machining Reshaping the object Olfactory Additive Manufacture Subtractive Manufacture Actuators Projection Stewart Platform Augmented Reality object	Slow Slow Slow Slow Medium Medium Medium Fast Fast Fast
User	None Voice Gaze Gesture Motion Capture Rigged Model	Scribe Animation RFID Microphone Eye tracking Hand tracking Inertial tracking Computer vision	Slow Slow Medium Fast Fast Fast Fast Fast	Olfactory Haptic Audio Visual Functional Tangible	Medium Fast Fast Fast Fast Fast
Environment	None Image Video 3D Model Point Cloud	3D Modelling Photogrammetry SLAM Camera	Slow Medium Fast Fast	Computer graphics Human actuated Virtual Reality Augmented Reality Object Environment rendering	Slow Medium Fast Fast Fast
Metadata	Designer Date Iteration number Design rationale Design intent	Transcribe Text input Speech to text	Very Slow Slow Slow	As required Augmented Reality Object	N/A Fast

(Kent et al. 2021) even better review, with *Dimensions of value* as a way to structure applications of mixed reality. The 5 dimensions are: Creation & Configuration; Visualisation; Knowledge Management; Integrated Analysis; Collaboration. For our work, it is interesting to trace the interaction modes provided in the value dimensions of Creation & Configuration and Collaboration (a total of 61 papers).



(Arora et al. 2018) references Tiltbrush and other. They present “SymbiosisSketch, a hybrid sketching system that combines drawing in air (3D) and on a drawing surface (2D) to create detailed 3D designs of arbitrary scale in an augmented reality (AR) setting.”

(Arrighi and Mougenot 2019) present a system aiming to be a configurator in AR, using 3D printed objects with AR marker to represent furniture items. Note: the system can be used to define the constraint lines (guide curves) or the irregular mesh method.

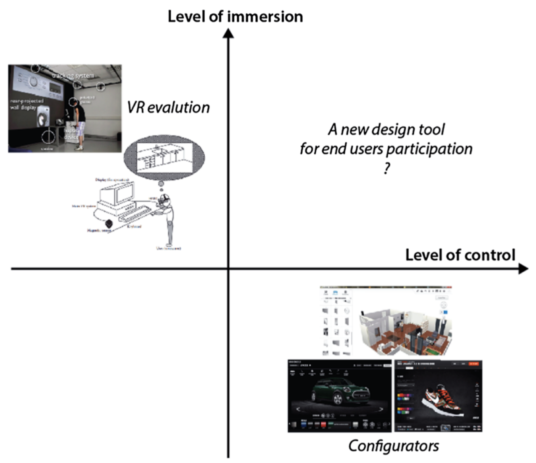
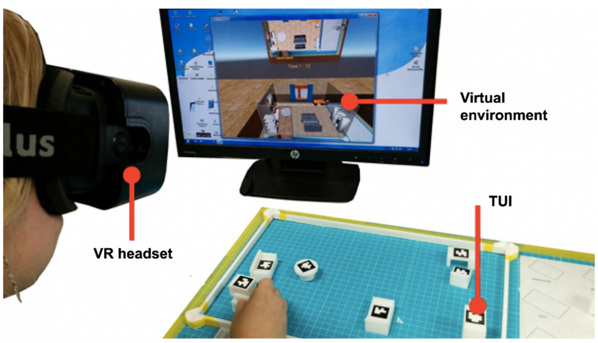
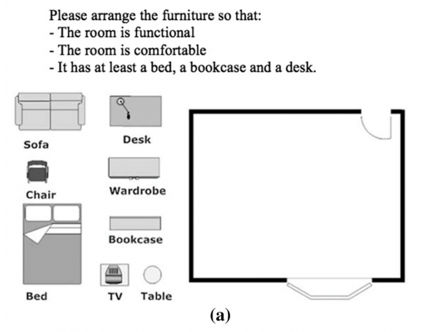


Fig. 6 A new tool that simultaneously offers high level of control and immersion



(Maurya et al. 2019) earlier report of the same experiment as (Arrighi and Mougenot 2019).



(Fröhlich et al. 2018) use gestures to enable VR users to decorate a landscape surface with trees and buildings. The users pinch an UI Buble element and move it over the surface to 'pour' the objects instances. The authors report the gesture lacked precision.

(Gai et al. 2017)present a system using mobile phone to layout mazes and walk in them virtually. It merges 2D and 2.5D into one environment and allows the configuration as well as the immersive experience to happen on one device. However, it relies on custom-made physical artefacts to model the maze which we aim to avoid in our work. Furthermore, it only offers the 1:1 scale of interaction and layout definition. The scaled-down object mode which can be much easier in defining the layout is missing.

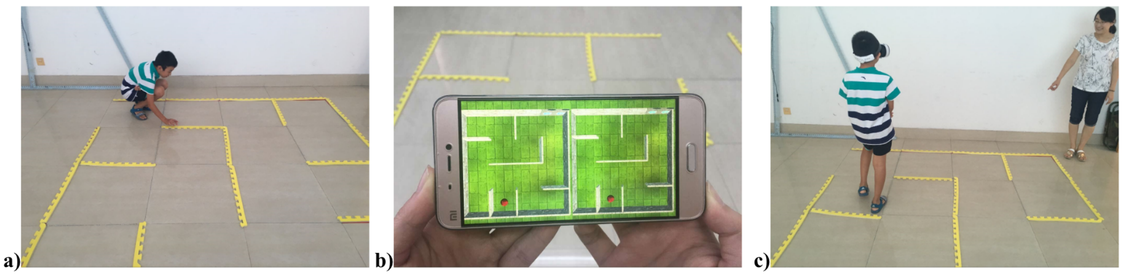
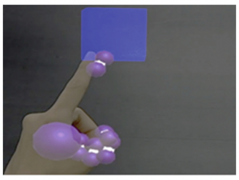
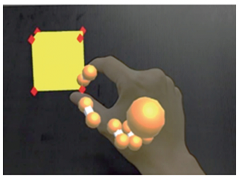
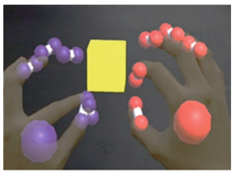
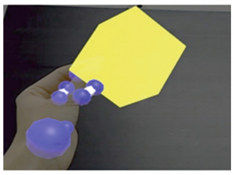
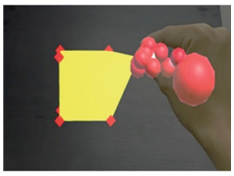
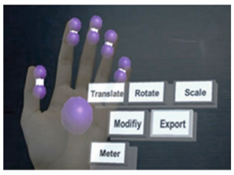
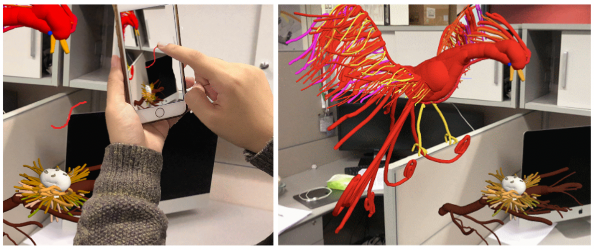


Figure 1. Illustration of the design and play of a maze on a mobile device: a) Design a maze on the floor, b) Generate a 3D maze; c) Play in the maze.

(Jailungka and Charoenseang 2018) present a system for 3D modellign in AR with direct output to 3D printing. Tested only on primitives.They use Hololens, Leap motion for hand gesture tracking and a desktop FDM printer.

Gesture Commands	Features	Definition
	Object Selection	The object selection feature is used to select the holographic object at the tip of index finger pointed on holographic object by tapping gesture. This feature sends the tip position of index finger (X_{tip}, Y_{tip}, Z_{tip}) and tap command.
	Object Translation	The object translation feature is used to move the position of holographic object by pinch gesture. The holographic object can be moved along axis in 3D space. This feature sends the new position at pinch position (X_t, Y_t, Z_t) and pinch command.
	Object Scaling	The object scaling feature is used to enlarge or shrink the holographic object by pinching two hands. This feature sends the detected pinch positions from left hand and right hand including pinch command.
	Object Rotation	The object rotation feature is used to rotate the orientation of holographic object along axis by grabbing the holographic object. The factor value of orientation increases the orientation of holographic object along axis while the arrow is grabbed.
	Object Deformation	The object deformation feature is used to move the vertex position of holographic object in 3D space by pinch gesture.
	Hand Panel	The hand panel feature is GUI panel for mode selection such as translate, rotate, scaling, modify, meter, and export a STL file format.

(Kwan and Fu 2019)present a system for sketching in 3D using AR on a mobile device. The authors state it is for users with reasonably good drawing skills to create 3D concept designs in the context of real-world environments. Our goal is to create a system for user with now sketching skills.



(a) 3D sketching in mobile AR   (b) “Phoenix” (34.2 mins)

(Millette and McGuffin 2016)present a system where the user edits a 3D AR scene by sketching and modelling 3D objects using a mobile phone and then placing them in the scene. The authors call it Draw-and-Drop.

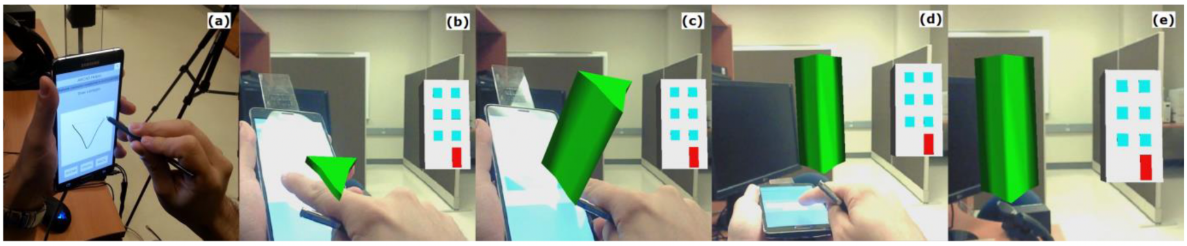


Figure 3: The Draw-and-Drop interaction technique. The user draws a polygon using the stylus (a), the polygon becomes a prism (b) which is then extruded by sliding a finger (c), moved into position on the scene (d) and finally detached (e).

(Reipschläger and Dachselt 2019) present a system using a touch screen with a pen and a hololens. The user uses the screen to model basic shapes and sees results in AR. modelled object can be instantiated next to modeling area. No layout mode, just 3D. Intuitive modelling but requires special hardware.

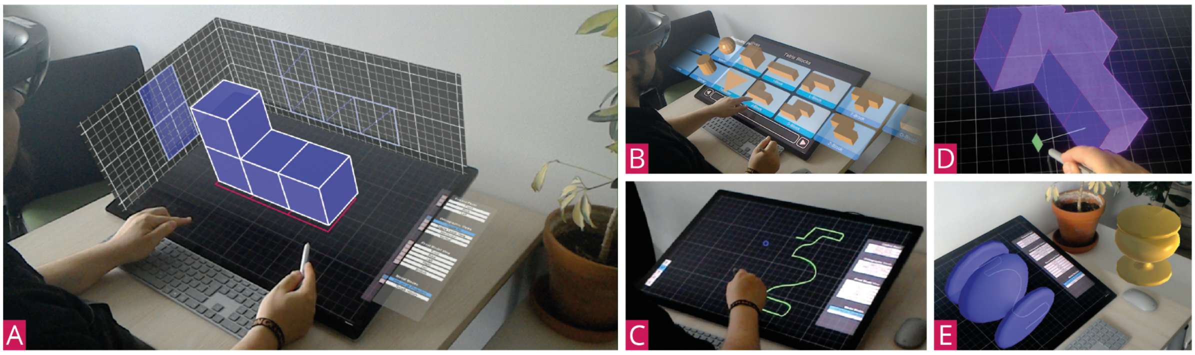


Figure 1: A general overview of *DesignAR*, highlighting (a) the augmented workstation as a whole, (b) The AR object browser, (c) sketching contours, (d) modeling by extruding faces, and (e) rotational solids and AR instances.

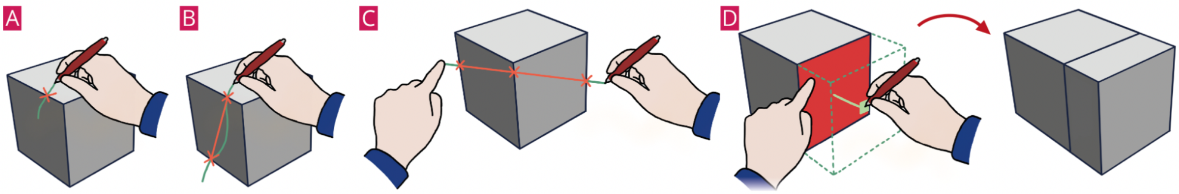


Figure 3: Sketches illustrating our interaction techniques for refining 3D models: (a) creating a new vertex by crossing a single edge with a pen stroke, (b) creating a new edge by crossing two or more edges with a single pen stroke, (c) slicing the whole model by using pen and touch to define a slicing plane, (d) extruding a face by first selecting it with the finger and then dragging it out with the pen.

(Roo and Hachet 2017) present a framework where the users interact with physical objects and virtual content in different modalities. The authors explor various relationships between users' avatars/bodies and the objects they manipulate is only one, namely at the object scale modes and immersive environment 1:1 mode. The authors present this with a clear diagram of 6 levels of the gradient between physical and virtual realms. However the immersive mode is treated purely as representational experience. In out work we aim to enable the user to edit the design in both object and 1:1 modes.

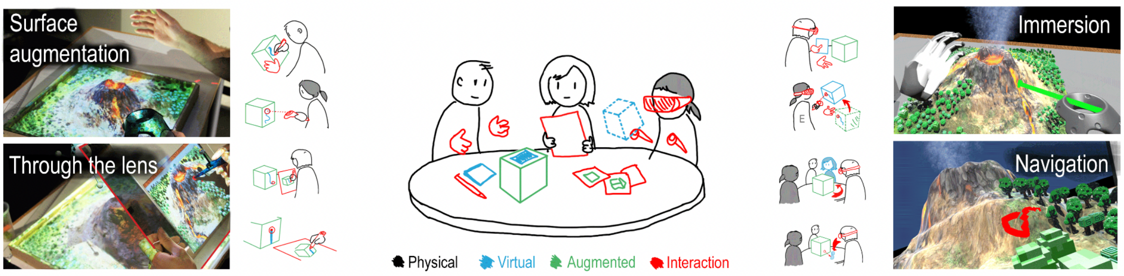


Figure 1. The presented system, exemplified here by an augmented volcano mock-up, allows one or more users to use and transition between multiple mixed reality modalities while interacting with augmented artifacts. The increase in instrumentation provides increasing flexibility, while keeping the interaction framed in the physical world.

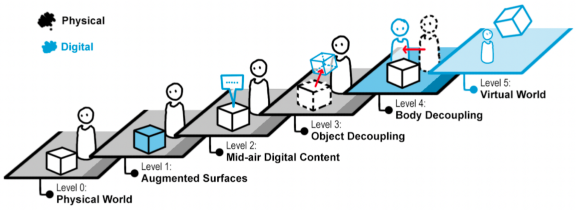


Figure 3. Conceptual framework with 6 levels of incremental augmentation, from Physical to Virtual worlds.

(Son et al. 2020)present a system that uses projection mapping and physical objects to find and display floor plan layouts matching a user defined criteria such as boundary, number of rooms, etc. The system also lets users try various wall textures on their designs. Works only at object scale, no 1:1 walk-through mode. It does only walls and room types, no doors and windows. There system is complicated to set up and requires the physical objects. As an outlook of our work various retrieval methods can be tested so users do not have to draw the floor plans but draw their boundaries for example.

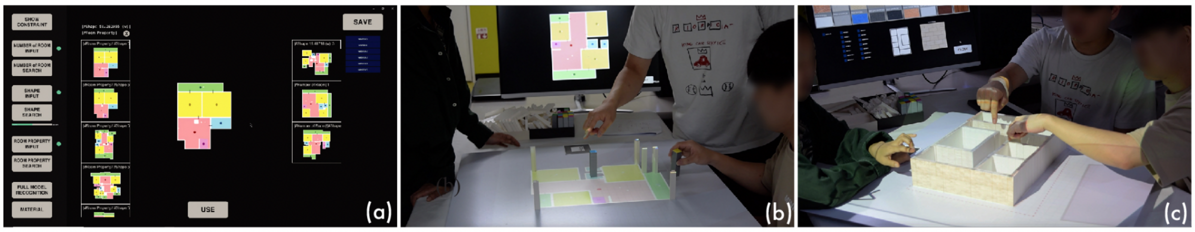


Figure 1. An interactive design process through C-Space: (a) retrieving design references through graphical user interface; (b) discussing and altering the retrieved references through tangible user interface; (c) testing finishing materials using projection mapping.

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