Drawing From Life: Interaction Techniques for 3D Drawing From Observation in Mixed Reality

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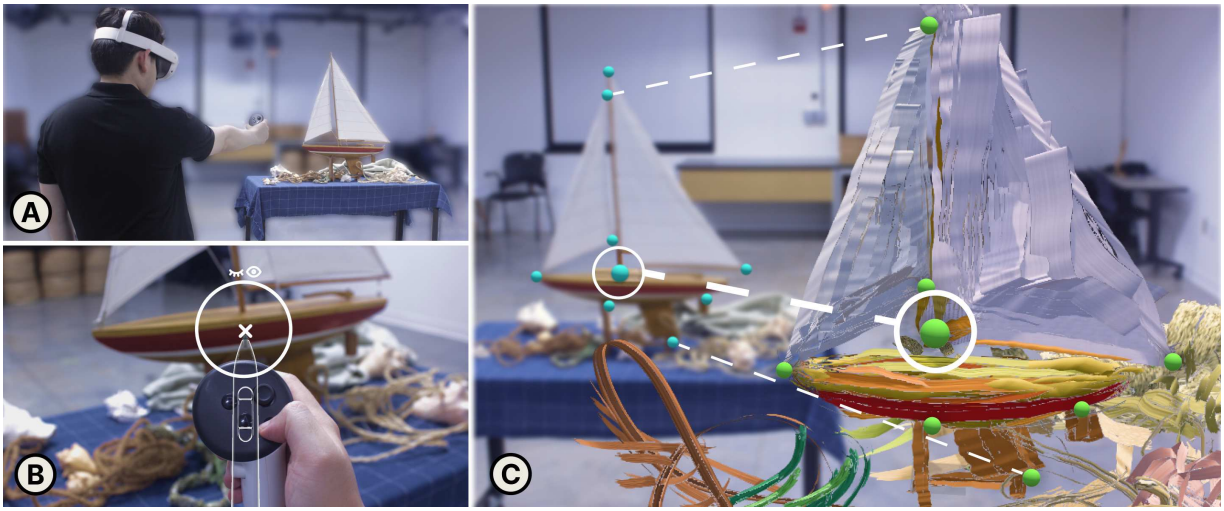

Figure 1: 3D user interfaces for Drawing From Life in augmented/mixed reality (AR/MR) intentionally foster close visual observation of a real-world subject while drawing in virtual space. Multi-View Sighting is one example. (A) Artists observe a subject they want to study, and (B) "sight" real-world reference points on the subject, which are (C) visualized on both the real-world subject (cyan points) and in the local space of the artist's 3D drawing (green points). The result is a set of visual guides derived from direct visual observation of the subject that make it easier to draw in correct proportion while also leaving room for artistic interpretation.

Abstract

We present our vision for Drawing From Life in mixed reality (MR) along with interaction techniques developed to support observational 3D drawing. While 3D drawing in (semi-)immersive environments has been studied for decades, the work has not emphasized learning the skill of observation, which, in contrast, is foundational to traditional drawing instruction. We demonstrate novel interaction techniques to address this new emphasis, including a multi-viewpoint 3D "sighting" technique and proportional ruler inspired by the traditional sighting artists do with a physical pencil or paintbrush. The approach demonstrates how real-world observations of a subject can be mirrored in a virtual Artwork Space that provides a scaffold for 3D drawing with correct proportions. The new tools were deployed in two semesters of a university course, 3D Drawing in eXtended Reality. Results include a characterization of expected sighting accuracy, example observational 3D drawings, analysis of proportional deviation in drawings and methods to compare to ground truth, and rich feedback from student 3D drawers.

Index Terms: 3D Drawing, Input Techniques, Mixed Reality

1 Introduction

The practice of drawing from life–drawing real-world subjects from visual observation–is tens of thousands of years old. Throughout history, observational drawings have factored importantly in all aspects of society, from scientific discoveries to social change. Today, advances in virtual, mixed, and augmented reality (VR, MR, AR) have expanded drawing to 3D virtual spaces, providing an unparalleled expressive power to artists and scientists. Yet, the potential to engage these powerful technologies in the fundamental human activity of drawing what we see, remains largely untapped.

3D drawing, including variants known as 3D sketching and 3D painting, is a form of technology-enabled drawing where: *1. the physical act of mark making is accomplished off-the-page in a 3D, body-centric space, 2. a computer-based tracking system records the spatial movement of the drawing implement, and 3. the result is often displayed in this same 3D space, e.g., via the use of immersive computer displays, as in virtual and augmented realities* [32]. This more flexible, virtual, 3D form of drawing has captivated researchers since at least the 1990's (e.g., [7, 10, 14]). Recently, in the new era of affordable, widely available VR displays, 3D drawing has also established itself in popular culture and the creative disciplines, with vibrant communities of practice forming online [6, 48]. Early applications of 3D drawing have advanced art practice (e.g., [15, 36]), product and architectural design (e.g., [20, 43]), scientific data visualization (e.g., [26, 40]), and engineering and medical device design (e.g., [21, 50]).

Artists say, to learn to draw, you must first learn to see; yet, technical research on 3D drawing has proceeded differently, with an initial focus on supporting motor skills and 3D mesh generation rather than observational skills. The research has nonetheless been exciting and innovative, defining a variety of forms that can be generated from mid-air drawing movements (e.g., [10, 45, 49]) and deeply considering the issue of how best to control a mid-air drawing implement, resulting in innovative spatial user interfaces

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for one- and two-handed drawing along with a host of haptic and virtual guides (see Related Work). Collectively, these techniques largely solve the important "motor control" challenges that arise when drawing in the air rather than on paper, that is, assuming the artist knows the correct lines to draw, as in a tracing task.

Compared to tracing, drawing from life is more challenging because it requires coupling motor skills with observation and interpretation skills. Supporting these combined skills has not yet been researched. In VR, where users cannot see the real-world around them, artists must either work from memory (limiting the choice of subject) or invent workarounds to see their subject (e.g., repeatedly removing a headset, or giving up one wall of a 4-wall CAVE to display reference photographs [23]). Some 3D drawing research has been conducted with AR displays (e.g., [54, 57]), where a real-world subject can be viewed simultaneously with mid-air digital content. Now that such displays are more readily commercially available, they will certainly be preferred for observational 3D drawing. Still, the current paradigm is to improve the pen, not the eye. What if the technologies could do more to support observation, the skill artists say should come first when learning to draw?

In this paper, we call this new paradigm of observation-focused 3D drawing in MR *Drawing From Life*, and we introduce a first set of 3D user interfaces to explore how observation can be fostered and supported, while maintaining the ability for creative expression. Drawings created from life often address serious subjects. To imagine the style of close observation we aim to support, think of a medical illustrator studying a fossil while creating a textbook illustration or a geologist sketching the rock formations they see while standing in the field. In these situations geometric accuracy is important, but the most powerful uses of observational drawing blend accurate real-world observation with human interpretation. For example, scientists drawing what they see through microscopes, and in particular, *processing and interpreting their observations through the act of drawing*, have made award-winning discoveries [17]. Building upon the artistic tradition, our technical approach is inspired by established observational drawing techniques, such as the Sight-Size method [5, 8]. The specific contributions of this paper are:

- A call to action for a next phase of 3D drawing, sketching, and painting user interface research to integrate, support, and teach close observation of real-world subjects–making it possible for 3D drawing to function, like traditional drawing, as a mode of visual study, inquiry, and interpretation.
- A novel 3D user interface technique, called Multi-View Sighting, and associated concepts that demonstrate the vision by making it possible to sight and edit reference points on a real-world subject, mirror them in a linked virtual space, convert them into proportional rulers, and create 3D drawings based, fundamentally, on these observations.
- Example observational 3D drawings and related results from studio classroom deployments including a characterization of expected sighting accuracy, analysis of proportional deviation in drawings with methods to compare to ground truth, and rich feedback from student 3D drawers.

2 Related Work

2.1 Sketch-based 3D Modeling and 3D Drawing

Creating 3D models from hand-drawn input strokes is a classic problem in computer graphics that dates to Sutherland's sketchpad in 1964 [51]. In most sketch-based modeling research, algorithms and user interfaces are developed to transform *2D input strokes* (from a tablet, for example) to a variety of 2.5D (e.g., [11, 52]) and 3D (e.g., [19, 61]) representations. (See also a survey of Sketch-Based Modeling research [41].)

Our research is in a complementary form of sketch-based 3D modeling based on *3D input strokes*. This is often called 3D drawing [47], 3D sketching [10], or 3D painting [25]. Several drawing interfaces expand the utility of 3D drawing by making the medium more controllable. The approaches include bimanual techniques inspired by the traditional practice of drawing with a roll of tape, as used in car design, either with [24] or without [16] haptic feedback. Dynamic techniques that adjust the brush in response to drawing speed and curvature are also useful [27]. Using a VR controller or pen rather than bare-hand interaction also increases control [9].

While these techniques improve the "brush", a complementary approach is to add a "ruler" or a guide. Some guides are physical, such as drawing with a pen on the physical surface of a table or wall [2], or on a virtual plane with active haptic feedback [38, 55]. While these guides improve control, they also limit the artist to creating planar strokes. Other guides only provide visual feedback [53], with geometric shapes inferred from strokes already drawn [22, 35]. Yet other guides snap or beautify 3D strokes relative to reference planes [33, 64] or 3D scaffold surfaces [28, 29, 58, 60]. Our work is complementary and could likely be incorporated into several of the methods as a way to create guides from observation.

While the majority of 3D drawing research has been done with immersive displays that do not provide a view of the real world, several systems have been developed for (or can be used with) AR and MR displays that do not completely block the real-world from view (e.g., [12, 44, 63]; see also a survey on AR sketching research [4]), and this opens up more potential for drawing from real-world observation. Multiple AR 3D drawing systems support or encourage *tracing* a 3D subject [54, 59]. It would be interesting to explicitly compare tracing to our approach. If the user adopts a mindset of close visual observation while tracing, then tracing might achieve some of the same benefits as our interfaces, which are intended to work from a distance. However, a recent study [39] found that users move their heads less while 3D tracing, suggesting decreased dynamic exploration and observation. Based on examples demonstrated in the research and experiences of artists incorporating 3D tracing in their practice [62], 3D tracing seems to lend itself more to quick approximate shape capture rather than deep visual study. AR 3D drawing systems have also used 3D-scans of real-world geometries as a real-world canvas or guide [56]. Our approach similarly involves drawing in a virtual space that is constructed from a representation of the real world, and our approach could be extended to make user-generated sightings act as constraints. The difference is, again, in the user's task–our approach encourages (even requires) the user to physically and carefully observe the real-world subject. In this way, our approach is closer to traditional observational drawing techniques, such as the Sight-Size method [8, 5], that re-purpose the tools artists are already holding (e.g., a pencil) to aid observation (Figure 2).

2.2 2D Drawing with Real-World References

While our focus on supporting real-time human-made observations for 3D drawing is unique, other work has incorporated real-world references in 3D modeling processes based on 2D input. These include automatically generating construction lines from reference images [18, 31], providing automatic feedback on value and color [31], and combining references from multiple sources including real-world measurements [42, 46]. Building on the earlier discussion of serious subjects, the final examples, which are applications to architectural design and cultural heritage, are notable in the ways they intentionally combine data-driven/algorithmic methods with creative, human input from sketching.

3 Drawing from Life Interaction Techniques

A variety of new interaction techniques could be developed to support a new paradigm of observational 3D drawing in AR/MR. We suggest two high-level user interface Design Requirements (DR):

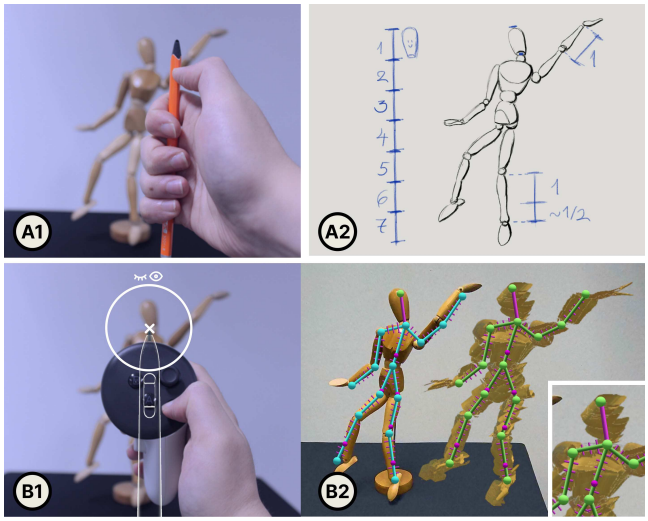

Figure 2: (A1-A2) With the traditional observational drawing strategy called, *sighting*, the artist closes one eye and extends their arm. Then, using the tip of the pencil and their thumb, they define a relative unit of measurement (e.g., one head). Next, they move the pencil and thumb, with arm still outstretched, to other parts of the body to visually measure lengths in "units" of the head. (B1-B2) Our vision for *Drawing From Life* reinterprets sighting as a multi-view 3D technique.

DR1: Fluid integration with an established creative process. 3D drawing feels immediate and gestural, and new techniques to support observation must preserve this, fitting as tightly within the creative process as the traditional observational tools and strategies.

DR2: Fostering close observation. The new interaction techniques should not just function as a technical tool to increase accuracy, but rather contribute to learning the skill and fostering a practice of close observation, helping to expand the use of 3D drawing for addressing serious real-world subjects.

In the sections below, we describe a novel 3D interaction technique, called Multi-View Sighting, along with related concepts, such as techniques to edit sighted points, linking Artwork and Subject Spaces, using sighting to establish a common coordinate system (i.e., platform) for the subject, and connecting lines between points. Together, these illustrate the types of 3D user interfaces that we believe will be useful to support 3D *Drawing From Life*.

We implemented the techniques in an application written with the Unity game engine. Users provide input via two handheld controllers, each with one trigger button and one grip button. The artist holds a stylus in the dominant hand and a virtual palette in their non-dominant hand (Figure 3). The application includes the basic features required to be successfully used by students in a studio art course (e.g., capability to resize the brush, a color picker, a texture picker, strokes with ribbon or tube shaped geometries, saving and loading 3D drawings, artwork layers). It also includes implementations of several one- and two-handed drawing techniques to facilitate comparisons [25, 24, 27], along with the new user interfaces introduced in this paper.

3.1 Multi-View Sighting

Our reinterpretation is not an exact replica of traditional sighting since several aspects of the original are specific to creating a perspective projection of the scene on the 2D plane of the paper. We designed the interaction to feel similar and similarly assist with drawing observed subjects in correct proportion. Figure 4 illustrates the key steps of the interaction. (A1) After activating the sighting tool, the artist stands roughly 1–4 meters from the subject

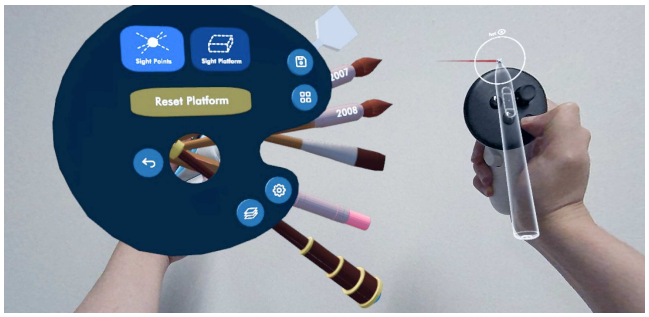

Figure 3: Artists hold a virtual palette and an array of possible tools in their non-dominant hand, while the currently active tool is held in the dominant hand. The active tool can be swapped by selecting a brush, the eraser, or the telescope; this also updates the palette to display any tool-specific settings. The telescope is used for sighting, and it is selected in this figure.

and closes one eye, leaving the other eye, which we call the **sighting eye**, open. The virtual tool held in their dominant hand includes a **sighting reticle**, a circle marker with an X in the center, located at the tip of the virtual stylus (see Figure 2 B1). Using their sighting eye only, they look through the sighting reticle, moving it with their hand to align the X with a feature on the real-world subject, such as the top of the head or the chin. We call this real-world point the **subject point**. Finally, they press and release the primary button of the stylus. We call this entire sequence conducted from a single viewpoint relative to the subject an **observation**. Since this is the first observation of a new subject point, the operation generates a **sighted ray**, visualized in the software with origin at the sighting eye and direction passing through the location of the X of the sighting reticle at the time the stylus button was released.

The next step is to conduct a second observation of the same subject point. The artist moves to a new viewpoint and looks at the same subject point. As they move the sighting reticle toward the subject point, the reticle will appear on top of the sighted ray created in the previous step. This selects and highlights the sighted ray. (Comparing inset A1 to A2 in Figure 4, the view through the sighting reticle has changed.) Highlighting a previous observation like this, indicates that making a new observation now will group the observation together with the highlighted one, associating both with the same subject point. The artist presses and releases the stylus button to confirm this operation. Now that a minimum of two observations are associated with the same subject point, the visual representation updates, and the sighted ray becomes a **sighted point**, located at the intersection of the two observation rays.

In practice, sighted rays do not intersect perfectly. As shown in Figure 4 B, we compute a best-fit intersection point that minimizes the distance to each sighted ray. For rays with origins a_i and unit directions $\vec{d}_i$, we solve for point p minimizing $\sum_i(\vec{d}_i \times (a_i - p)) \cdot (\vec{d}_i \times (a_i - p))$. Our implementation formulates this as a linear system and solves for p using Gaussian elimination.

3.2 Selecting and Refining Sighted Points

Optionally, drawers can further refine sighted points as they move around the subject and observe from new viewpoints and/or as the subject moves slightly. To accomplish this in a way that fits within the creative workflow (**DR1**), we extended the core sighting interface to support: (1) selecting sighted rays and points, even in dense spatial configurations; (2) returning to edit any prior observation, regardless of the creation order; and (3) interleaving observations for editing sighted points (and rays) and creating new sighted rays.

The sighting reticle naturally supports an aperture-based selection technique [30, 13]. We can think of it as defining a cone in

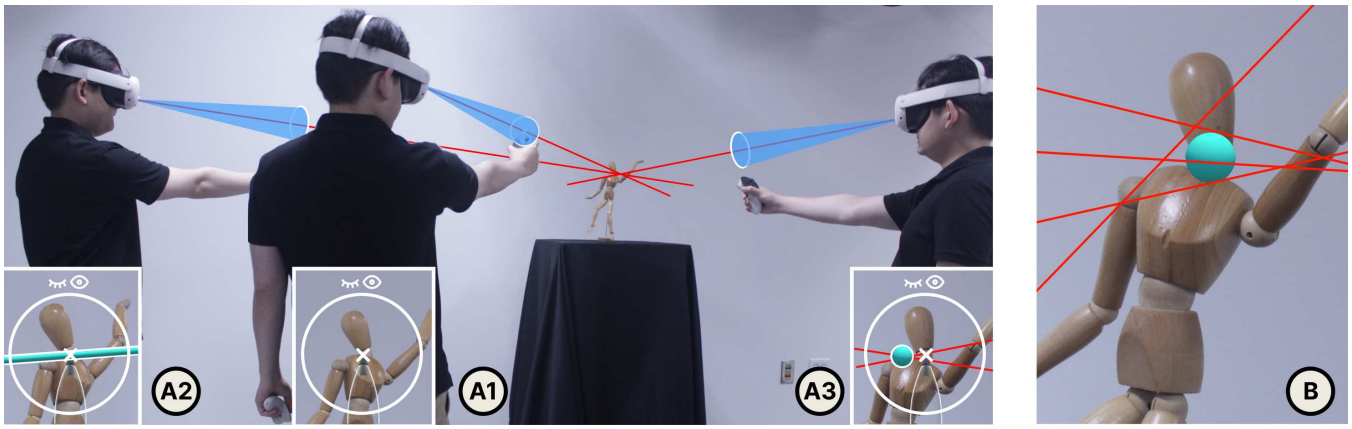

Figure 4: (A1) Looking through the *sighting reticle* with one eye, aligning it with a feature on the real-world subject (e.g. the mannequin's chin), and confirming with a stylus button makes an *observation* and displays a *sighted ray*. (A2) Moving to a different viewpoint, highlighting the *sighted ray*, and confirming with a stylus button adds a second observation, creating a *sighted point*. (A3) Optionally, adding additional observations refines the sighted point. (B) Sighted points are defined via a least-squares solution for the intersection of two or more observation rays.

space with a tip at the location of the sighting eye and a circular cross-section passing through the circle of the sighting reticle (Figure 5 Top). This cone defines the bounding volume to search when selecting sighted points. If the cone overlaps a single sighted point or line, then it becomes selected. If it overlaps multiple points and/or rays, then the one whose projection onto the plane of the reticle is closest to the X is selected. Making an observation while a sighted point or line is selected adds the observation to the selected object, turning a sighted line into a sighted point if it is the second observation, and refining (editing) the sighted point otherwise. If nothing is selected, the observation creates a new sighted ray.

Artists can customize the selection technique to best match the observed subject in several ways. First, the sighting cone shape can be adjusted by moving the stylus: from the monocular viewpoint of the sighting eye, moving the stylus toward or away from the eye narrows or widens the cone angle, respectively (Figure 5). Second, artists can independently adjust the sighting reticle radius using the same interaction for resizing drawing tools: holding the non-dominant hand trigger scales the tool size proportionally to the distance between the hands. A key design decision is that selection is recorded on the stylus button-down event, while the observation is recorded on button-up. For challenging selections, artists can move the reticle away from overlapping points, press and hold the trigger to lock the selection, reposition the reticle for the desired observation, and release the button to confirm the operation.

3.3 Proportional Rulers between Sighted Points

Another extension of the core sighting interface involves connecting sighted points with lines. The lines are specified by selecting pairs of sighted points with the sighting reticle and confirming with a secondary button on the dominant hand stylus. The connections are visualized as shown in Figure 2 B2. Building on the traditional observational drawing workflow, the lines also serve as proportional rulers. The distance between the first two connected points defines a unit of measurement, and this connection is visualized in magenta (see inset). Subsequent connections (shown in green) are marked with small magenta spheres at each unit length with four equally-spaced tick marks between each.

3.4 Representing Observations Across Spaces

It is useful to explicitly define the three coordinate spaces indicated in Figure 6: **Tracking Space** is for reporting raw input from the AR/MR head-mounted display and controllers. **Subject Space** is

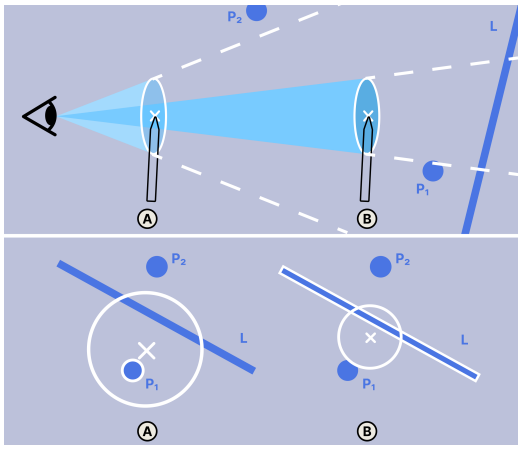

Figure 5: Sighted points and sighted rays are selected via an aperture-based technique. Holding the arm closer (A) or farther (B) from the eye, naturally adjusts the size of the selection cone, as seen from the side (Top) and the sighting eye (Bottom).

defined relative to the real-world subject. (In some implementations, like a CAVE, the origin and axes of the Subject Space correspond directly to the Tracking Space.) Finally, **Artwork Space** contains the virtual brushstrokes drawn by the artist.

Sighted points are visualized in both Subject Space and Artwork Space, with the Subject Space visualization serving as the original reference, and the Artwork Space visualization serving as a guide for artists. The Artwork Space can be translated, rotated, and scaled independently of the Subject Space, making it possible to work at comfortable orientations and allowing the artwork to be overlaid on top of, or next to, the subject at the same scale and orientation.

3.5 Creating a Reproducible Subject-to-Artwork Relationship by Sighting the Platform

The final related user interaction and 3D widget to describe is the **Platform**. This is a virtual representation of a rectangular surface that supports the subject. In a studio classroom, this is often naturally defined by a physical box-shaped platform or rug on which a human model poses or by a table upon which a still-life is arranged. The platform concept helps address two important challenges in

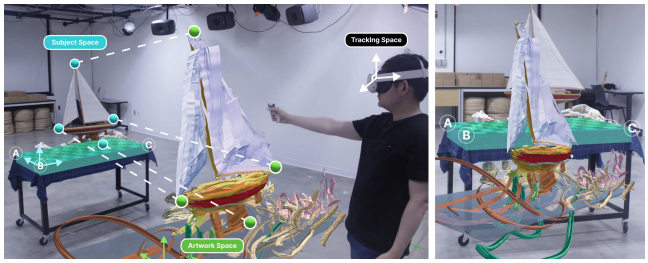

Figure 6: (Left): Sighting three corners of the platform holding a still-life (points A, B, C) defines the correspondence between the Tracking Space and Subject Space. (Right): The Artwork Space can be scaled, rotated, and translated independently from the Subject Space to orient the artwork in a comfortable position for drawing. *The sighted points and the contrast on the platform in the figure have been enhanced for clarity.*

Drawing From Life. First, it helps users understand and see the relationship between Subject Space and Artwork Space. Second, since MR devices that use "inside out" tracking do not guarantee that the tracking coordinate system is aligned consistently with the room between sessions, we need a way to re-establish a consistent coordinate system relative to the subject to support working across multiple sessions, including saving and loading 3D drawings.

The platform is identified by sighting points at three of its corners (e.g., A, B, and C on the table in Figure 6). The Subject Space coordinate system is defined by averaging the vertical (y) coordinates of the three sighted points and projecting each point onto a plane at this height. Then, one point (Point B in Figure 6) is selected as the origin, and an orthogonal basis is created using the vector between the first two sighted points as the primary axis and projecting the third point to the nearest coordinate that satisfies a 90° constraint. A virtual representation of the platform is displayed in both Subject and Artwork Space. Thus, sighting the Platform immediately defines and visualizes the two spaces in the artist's headset. To work at a comfortable scale and orientation, the artist will regularly adjust the position, rotation, and scale of their artwork by 'grabbing' and directly manipulating it using the primary button on the palette hand. As they do, the virtual platform in Artwork Space moves with the rest of the artwork, continuing to provide a consistent visualization of the relationship between the two spaces. This can be seen in Figure 1 C and Figure 6, where the artist has moved the drawing nearby to continue working on it.

4 Deployment, Drawings, and Analysis

The research project coincides with the researchers' parallel effort to develop and teach a new graduate-level course, *3D Drawing in eXtended Reality*, piloted in Spring 2025 and taught for the second time in Spring 2026. The course is registered within Computer Science and taught in a studio classroom in the Department of Art using a hybrid format. Class sessions combine active drawing and critique from studio art with technical mini-lectures and research paper discussions. Each student "checks-out" a Meta Quest 3 headset for semester-long use in class and at home. Students work with multiple 3D drawing applications, including Open Brush [6] and the custom application described throughout this paper.

We designed our evaluations as deployment studies within this course[1], an approach with both strengths and limitations. The methodologies must conform to course schedules and enrollment while prioritizing student learning over research goals, requiring concessions such as an insufficient number of participants for statistical hypothesis testing. However, the strengths outweigh these limitations. This novel studio course provides a unique opportunity to report rich qualitative feedback and example drawings: (1) students learn 3D drawing as a serious medium, practicing multiple hours per week in and outside class, providing far more experience than a typical single-session lab experiment; and (2) students create *realistic challenging use cases*, drawing complex subjects such as the human figure rather than simple 3D shapes, requiring prior observational drawing instruction and practice that is impossible to achieve in a lab setting. Our goals for semester 1 were to get some preliminary feedback from students and develop an initial quantitative understanding of the accuracy future students could expect from the technique. Semester 2 built upon these results to evaluate the extent to which the technique supports DR2: Fostering Close Observation.

[1]All data collection and reproductions of students' work are used with permission and follow approved Institutional Review Board procedures.

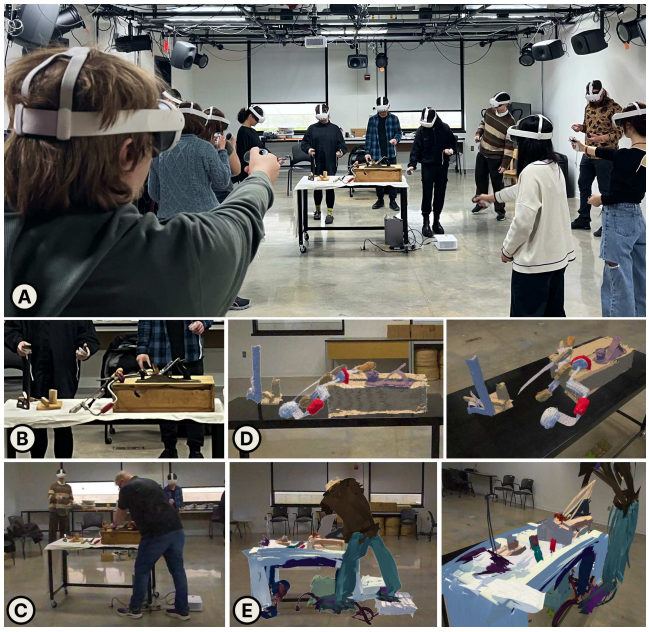

Figure 7: The 45-minute still life drawing from one of the final class meetings in Spring 2025. (A) The classroom environment, (B,C) the subject, a figure and collection of woodworking tools, (D,E) and example student drawings.

4.1 Semester 1: Confirming Use and Accuracy

The timing of our research project was not a perfect fit with the timing of the course in that the observational features described in this paper were only available late in the Spring 2025 semester. Students used them only in the last three class meetings. However, at this stage in the semester, they were already expert 3D drawers, and had already learned the user interface of our custom software (minus the observational features). Furthermore, their comments come from using the observational features in a long-duration (45 minute long) still life drawing of a figure standing by a workbench with a variety of woodworking tools (Figure 7 B, C). This was the longest single drawing session conducted during the semester–we viewed it as a culminating class activity, and students produced some compelling work (Figure 7 D, E)

Student Feedback. Feedback was gathered from all 14 students. Students reported, "This observational tool was such a missing piece in drawing in XR. It is such a useful tool when drawing in observational settings. When I was making my final project, I missed having the sighting tool, as it would have been super useful for creating the waterfalls." Another student commented, "Very

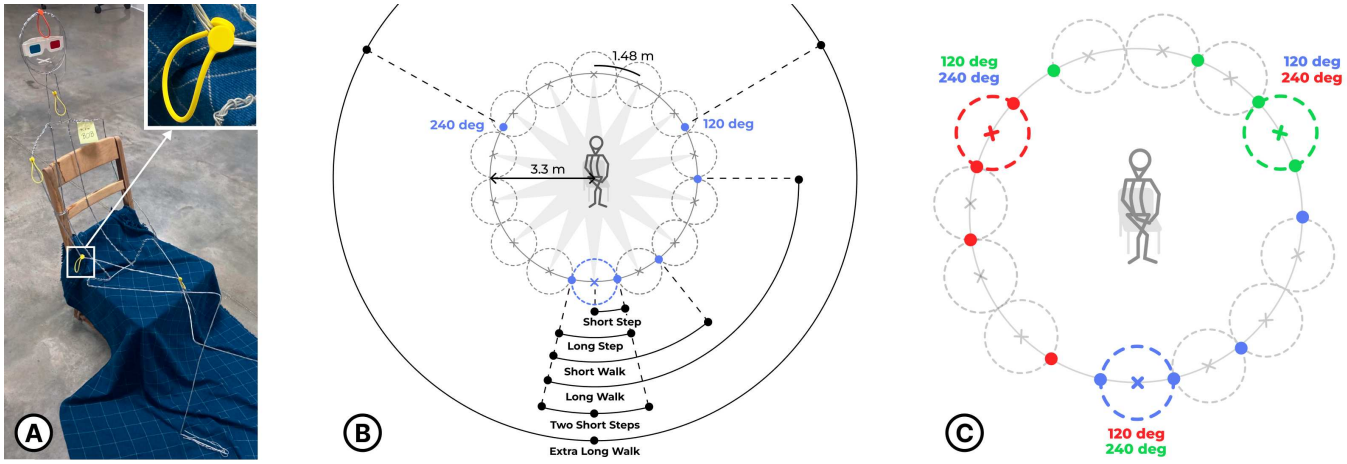

Figure 8: Design for characterizing accuracy. (A) "Bob" the human-scale model with 5 artistically important joints identified by yellow magnetic markers. (B) Illustration of sighting positions visited by a single student. (C) Illustration of the positions when expanded to three students.

useful—it trains precision, forces you to really look, and helps bridge the gap between virtual and real-world experience." A third said, "I think they're good for learning size and perspective through study." And another student, "I felt like it was much easier to have a steady or accurate line when I knew exactly where it was starting and ending, which can often be hard in the 3D space." Feedback in this style, provided early evidence of succeeding in meeting the second design requirement, **DR2: Fostering close observation**. The more critical feedback related to **DR1: Fluid integration with an established creative process**. In fact, one student stated this so clearly that their words essentially define the driving research question behind DR1, "The sighting feature is useful for tracking real world objects in virtual space, and there is value in this from a traditional drawing perspective. 3D drawing also shines the brightest via gesture and expression. The sighting feature is rigid, but the medium is fluid. How can these two things: tool and application, grow together?"

Methodology for Characterizing Accuracy. Beyond the preliminary feedback from students, we also wanted to develop an initial quantitative understanding of the accuracy future students could expect from the technique. Thus, we designed a way to take repeated sighting measurements from pre-determined distances and angles of specific points on a human-scale subject positioned at the center of the studio classroom. Our human-scale subject, known as "Bob", is pictured in Figure 8 A. Bob's proportions follow Robert Beverly Hale's cranial unit system [1] with a cranium size of 7 inches (approx. 18 cm).

Our methodology assumes students are already trained to proficiency. Thus, we recruited three expert 3D drawers from the course to participate in a study conducted in the studio classroom using their Meta Quest 3 devices. The environment emulated a figure drawing session with 14 students spread out in a large circle around the subject (Figure 8 B). Based on the classroom dimensions, we defined the radius of the circle to be 3.3 meters, which translates to each student having a personal workspace of diameter 1.48 meters. We marked five artistically important locations on Bob (top of the head, chin, right shoulder, right elbow, and right wrist) that were visible from all viewpoints using pairs of yellow, cylindrical magnets with diameter 1.25cm. The magnets in each pair are conveniently connected by a yellow tether, which makes them easy to locate (Figure 8 A inset).

The participants were tasked with repeatedly sighting the five joint markers from a series of viewpoints chosen to represent expected student movement. Accounting for physical and social boundaries, we identified six sighting scenarios that would be common in the classroom while also exploring the range of possibilities for sighting (Figure 8 B). Four of the six require drawers to observe the point from two separate locations: **1. Short Step Scenario:** First observation taken from the center of personal space; second from one step to the right. (This scenario is the least effort and expected to be the worst case scenario.) **2. Long Step Scenario:** First observation from the left edge of personal space, second from the right edge. (This creates the widest possible angle between observations without leaving the personal space.) **3. Short Walk Scenario:** First observation from left edge of personal space, second from the gap between the next two students to the right of them. (This reflects a move out of one's personal space to the closest clear line of sight.) **4. Long Walk Scenario:** First observation from the left of the personal space, second just beyond the third neighbor on the right. (This sets the angle between the two observations to what we expect will be ideal at around 90 degrees.) Two additional scenarios require three observations: **5. Two Short Steps Scenario:** From the left, to the center, to the right of a student's personal space. (This is the least effort for three observations.) **6. Extra Long Walk Scenario:** From the center of the personal space, to 120 degrees around the circle to the right, followed by another 120 degrees to the right. (This is the max effort for three observations, circling the full 360 degrees around the subject). All three expert drawers performed their observations simultaneously starting from the three positions indicated in Figure 8 C. They sighted each of the five marked points following scenario 1, then each of the five marked points following scenario 2, and so on. With 3 expert participants each sighting 5 marked points, the workflow resulted in 15 sighted points for each of the 6 scenarios.

To establish ground truth positions for the joint markers, we measured their 3D positions using the same Quest 3 hardware but paired with a Logitech MX Ink pen controller because it has a pointed tip that is easy to locate. Since it is impossible to place the tip inside each joint marker, we placed the tip on each marker 10 times, approaching each time from a different angle, and then averaged the results to calculate a final position. Next, since the sighted points and ground truth are defined in different coordinate systems, we register the datasets together using a Best-Fit Rigidbody Transformation [3]. Finally, we calculate the error for each sighted point as the Euclidean distance between the sighted point and the corresponding ground truth position.

Results: Expected Accuracy for Classroom Use Given the small sample size of this study, we report the results using plots and

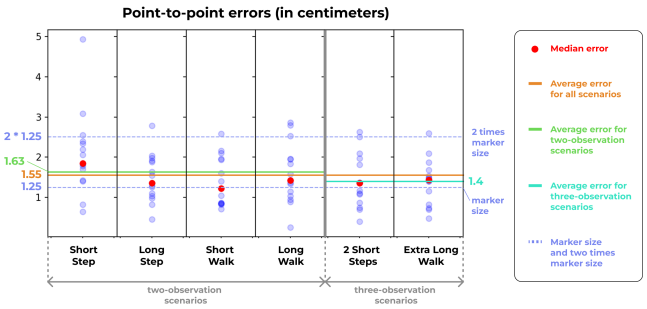

Figure 9: Sighting errors across scenarios. 15 error values (3 participants $\times$ 5 markers) are reported for each of the 6 scenarios.

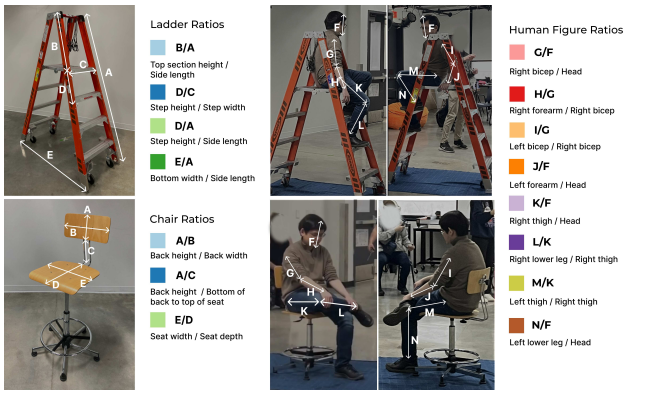

Figure 10: Drawing subjects with ratios for measuring proportions.

descriptive statistics only. Figure 9 is a complete view of the results, showing the error calculated for all 15 sighted points for each of the 6 scenarios. The plot also includes some lines to help contextualize the data. The dotted lines at 1.25cm and 2 * 1.25cm provide references for 1x and 2x the size of the physical yellow magnetic markers we placed on the model. We notice that for 87.8% (79 out of 90) of the sighted points, participants were able to achieve a positional error of less than twice the size of the magnetic markers. 68.9% (62 / 90) of the positional errors are less than 1.5x the marker size. In the two-observation scenarios, the average error was 1.63 cm, while the average error for three-observation scenarios was slightly lower at 1.4 cm. The average error for all scenarios was 1.55 cm, which is around 0.255 cm larger than the marker size.

Interpretation. Aggregating the data, essentially assuming that all scenarios occur frequently, the data show an average error of 1.55 cm. However, that assumes students walk around quite frequently. If we assume the opposite, that students rarely leave their personal space, the median error for the Long Step Scenario is 1.36 cm, and the median error for the Short Step Scenario, expected to be the worst case, is just 1.85 cm. To put this value in the real-world context of a life drawing course, assuming the average height of a human is 171 cm, the average error of 1.55 cm is just 0.877% of that. *This is far more than sufficient to confidently tell our students they can utilize the technique to judge the relative proportion of the head to the torso*. We can expect students who are well trained in 3D drawing to achieve a sufficient level of accuracy for typical use in a studio course.

4.2 Semester 2: Classroom Deployment

In Spring 2026, the second iteration of the *3D Drawing in eXtended Reality* course was taught with 12 students, with revised curriculum including specific instruction in observational drawing. In week 5, students completed traditional paper-and-charcoal pencil observational drawing exercises, learning strategies including blind contour drawing, negative space drawing, and sighting while drawing still lifes and figures. This section reports on activities in weeks 6 and 7, where students extended these concepts to 3D drawing.

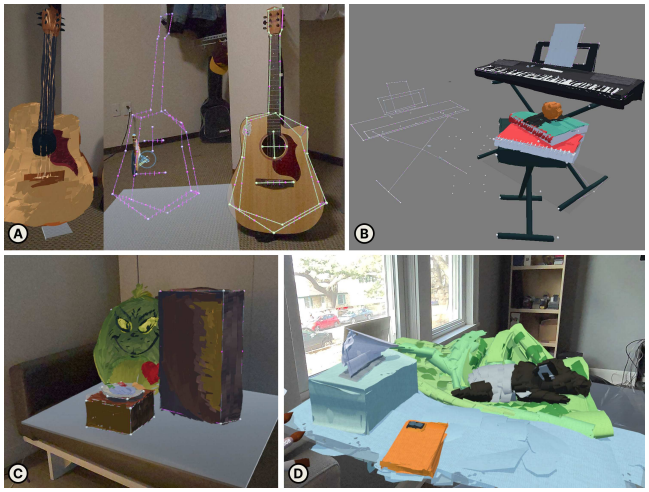

Figure 11: Homework drawings created using Multi-View Sighting.

By week 6, students were familiar with our custom 3D drawing software but had not used its observational features. We refer to this as Day 1 for Multi-View Sighting. Students learned the observational interfaces through a 45-minute interactive tutorial followed by a 15-minute practice drawing session. Given their prior five weeks of instruction and homework drawings, we considered this hour of instruction, including questions and confirmation of expected behavior, sufficient training to proficiency.

After a break, students completed two medium-duration (15-minute) 3D observational drawings of human-scale inanimate objects. The first subject, a ladder, was drawn *without* Multi-View Sighting, while the second, a chair, was drawn *with* Multi-View Sighting. The chair and ladder were selected because they contain multiple proportional relationships and are large enough to be sighted from about 3 meters away in a 12-person classroom.

Between weeks 6 and 7, students completed a homework assignment drawing a still life of their choice using Multi-View Sighting (Figure 11). In week 7 (Day 2), class began with critique and discussion of these drawings, followed by three rapid gesture drawings (2–3 minutes each) of standing figure poses. Students then completed two long-duration (20-minute) complex drawings of a figure posing *together with* the same ladder and chair from the previous week, with a 10-minute break between drawings. Subjects were swapped on Day 2 to counter learning effects while ensuring each was drawn with and without sighting techniques. At the end of Day 2, student feedback was collected through class discussion notes and a written questionnaire asking: (1) Describe your experience of 3D drawing with and without using the software's techniques for making observations; (2) Which do you prefer?; and (3) Do you have any feedback, suggestions, or anything else you'd like to share with us? Additional comments were welcome.

Visual and Proportional Analysis of Drawings Results are pictured in Figure 12. To measure the accuracy of proportions in student drawings, we identified key dimensions for each subject (line segments A–N in Figure 10), which we measured in centimeters on both the physical subjects as well as their virtual counterparts in each drawing. Ratios of the lengths represent proportions within the drawing (e.g., the height of the chair back to the width). We calculated the ratios defined in Figure 10 for both the physi-

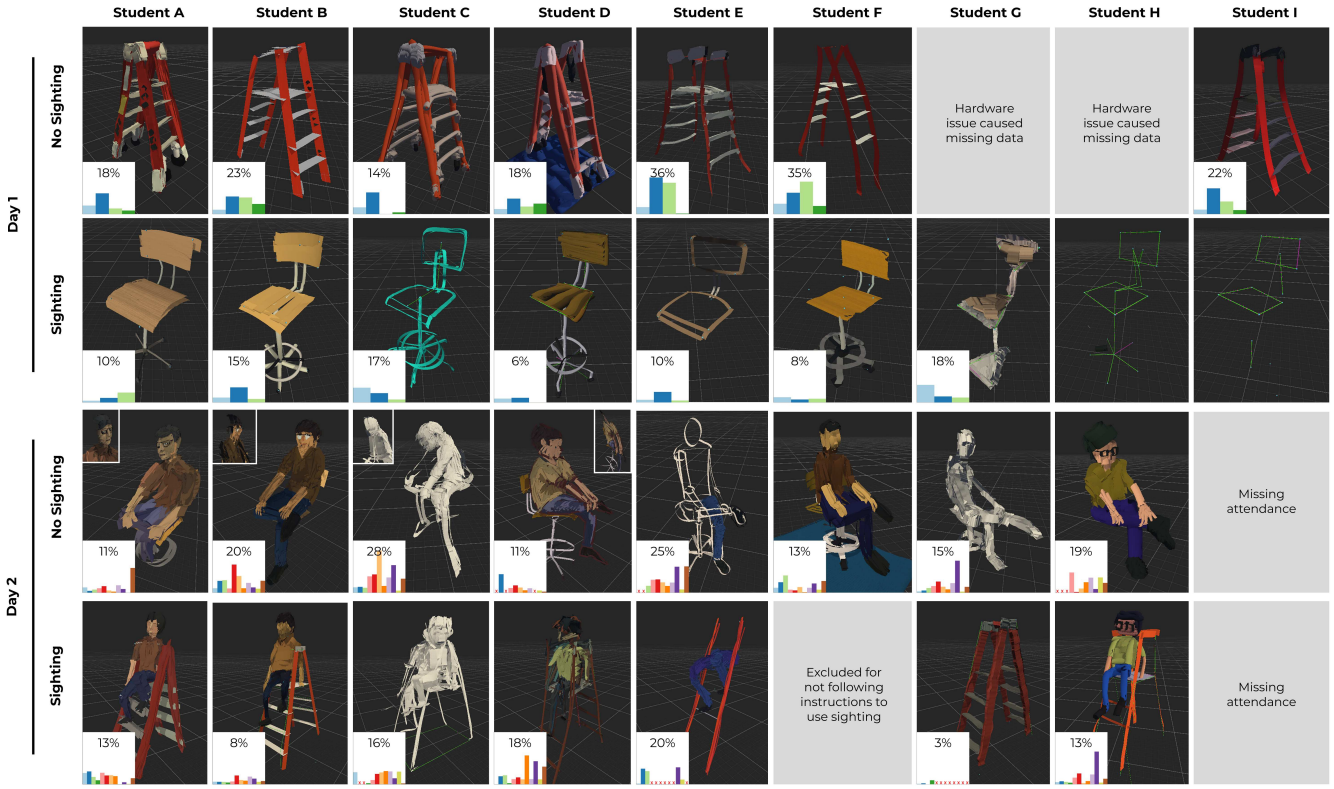

Figure 12: Drawings from Semester 2 deployment. The top two rows are Day 1, 15-minute drawings. The bottom two rows are Day 2, 20-minute drawings. Insets report the *average* proportional deviation calculated for the drawing. The colored-coded bars indicate the specific proportional ratios that contribute to this average (shown by the color mapping defined in Figure 10) and their values (shown by bar height, with height of 0% indicating perfect proportion and height filling 100% of the inset indicating an extremely poor 100% deviation.) Ratios that could not be calculated because students did not draw the corresponding portion of the subject are marked with an X.

cal subjects R_{actual} and the virtual drawings R_{drawn}. We report the percent the drawn proportion deviates from the actual subject: $Proportional\ Deviation = |(R_{drawn} - R_{actual})/R_{actual}| * 100$.

Drawings from nine of the 12 students were analyzed. Cases involving incomplete attendance, instruction misunderstandings, or hardware issues were excluded. One student missed Day 1 training, and two were excluded due to unreliable hardware data.

Comparing the Day 1 drawings in Figure 12 Top, chairs drawn with Multi-View Sighting appear better proportioned than ladders drawn without it. Student A's ladder is too short and stocky, while Students C and E drew rungs that are too wide relative to height, with incorrect rung spacing in most drawings. The chairs still show individual artistic differences, which we aim to support since the technique is not tracing, but their overall proportions look more accurate. Student G's chair demonstrates particular artistic freedom, using triangular shapes for the seat, back, and base. Despite having the highest proportional deviation among chairs (18.3%), it remains closer to the correct proportion than all but one ladder drawing (Student C). The median average proportional deviation was 22.5% (SD: 8.3) for ladders without Multi-View Sighting versus 10.4% (SD: 4.9) for chairs with sighting. These quantitative results reflect the visible differences in the drawings; however, in this context, we caution that the drawings, rather than the statistics, best convey their significance.

Comparing the Day 1 ladders to the Day 2 ladders with figures provides an opportunity to compare drawing without sighting vs. with sighting for the same subject because both drawings include a ladder. We know from student comments that the ladder with figure was by far the most complex and challenging drawing to do, but ignoring the figure for a moment, the ladders in the sighting examples look far better proportioned, and the data are consistent with this. Analyzing only the ratios from the ladder and ignoring those for the figure, the median of the students' average proportional deviation with sighting is 8.7% (SD: 6.5) vs. 22.5% (SD: 8.3) without sighting. Overall, the Day 2 drawings completed with sighting have slightly lower proportional deviation, with the median of the students' average proportional deviation being 13.1% (SD: 6.0), when compared to those without sighting at 16.8% (SD: 6.3).

The chairs on Day 1 are the most successfully proportioned subject of either day (median average proportional deviation 10.4%, SD: 4.9). Analyzing just the ratios of the chair and excluding ratios of the figure for Day 2, the median of the average proportional deviation is 13.2% (SD: 10.4). The higher standard deviation comes from the more gestural style most students used when drawing the chair on Day 2. Adding a figure to the chair increased the complexity of the drawing, and the figure immediately becomes the focus of the composition. So, it makes sense that most students focused on the figure and did not include much of the chair on Day 2.

Student D's seated figure is a unique case. Created without Multi-View Sighting, it is exceptionally well proportioned, with the second-lowest proportional deviation (11.1%) and a compelling use of color and layered strokes. However, from the side, the drawing is nearly flat, preventing computation of some proportional ratios. The student effectively transformed the 3D drawing exercise into a 2.5D drawing exercise.

Impacts on the Drawing Process. Students provided some rich feedback on how the interfaces impacted their process. Stu-

dent E describes drawing the chair with figure on Day 2 without sighting: "I started with creating a skeletal outline to set up proportions, which was very time consuming. I had to start from the bottom of the scene and work my way up to minimize proportional errors from stacking. I was only able to add some details and my proportions felt odd". Note, the gray construction lines that show the form of the body, but only the left foot and leg are drawn in their final intended form. Describing the process of drawing the ladder with figure using sighting, he continues, "I first quickly added keypoints, such as top and bottom ladder positions, foot, and knee. I was able to start from wherever I wanted in the drawing and add details quickly."

Student feedback varied with regards to the impacts on timing. Like Student E, Student G found that Multi-View Sighting sped up the process of creating a scaffolding, "less time to setup general proportions and guidelines". This student's drawing is often very precise. For the Day 2 ladder with figure, they devoted their time completely to the challenge of drawing the ladder, so much so that they did not get to the figure within the 20-minute time limit. However, this ladder was by far the most proportionally accurate of any drawing with an average proportional deviation of just 2.7%. Student A also described the trade-off between time and accuracy, remarking that it "helped immensely with getting the overall figure but did end up leaving less time for detailing." This can be seen in their ladder with figure that has fewer details on the face compared to the same student's drawing of the seated figure. Student C was more negative: "I felt I used up too much of the 15 minutes with setup that I was already half out of time". Note, how their day 2 drawings did not use color and are more gestural, indicating quicker movements.

Two students commented on how the interfaces made them feel more comfortable resizing the artwork, saying "I felt comfortable shrinking and expanding the drawing to make it easier to draw, which I did not do before, for fear of losing proportion." Students thought viewing the artwork at a one-to-one scale with the subject was useful for checking accuracy, but the ability to rescale the artwork is critical for adding details (e.g., in the figures' face) or changing to a scale where it is comfortable to draw larger subjects.

In the class discussions and on the questionnaire, multiple students discussed which important points they chose to sight on the subjects. For example, Student A described breaking the chair from Day 1 into parts. He sighted the four legs and the seat and back, making sure they were correct level from the floor. Student B reported, "For geometric shapes like a ladder, I create sight points at the intersections of perpendicular lines in the figure. I then connect them to make a skeleton which I can trace using the tape tool to give me nice and clean lines. For human and organic shapes, I use sight points at limb segments (elbows, feet, knees, head) and connect them to give me the skeleton of a person." The ability to describe the types of geometry that was sighted speaks to their observation and understanding of the subjects. This aligns well with our second design requirement of fostering close observation.

Preferences. Overall, eight of the 11 students present on Day 2 preferred the Drawing From Life interfaces. Students G and H were undecided, and Student C preferred drawing without the interface due to the additional time needed and feeling constrained by the sighted points.

Improvements. Feedback also included suggestions for future improvements. One student commented that the highlighting of the selected point when editing sighted points and rays sometimes occluded the subject feature they were sighting. Another wanted the capability to group sighted points for different things in the scene (such as a person and a ladder) and toggle each group on or off. The software already includes a layer system for the drawing strokes, but the sighted points are assigned by default to a single sighted point layer. This feature would be simple to add.

4.3 Discussion and Key Takeaways

The quantitative data from semester 1 show that expert 3D drawing students can use Multi-View Sighting to accurately sight points, which provide the necessary foundation for semester 2 results to evaluate DR2: Fostering Close Observation, where closer observation should improve drawing accuracy, detail, and proportion. The student drawings and quantitative results demonstrate that Multi-View Sighting improves proportional accuracy (a measure of skill) in realistic classroom conditions, while the qualitative data shows this scaffold gives students the confidence to diverge intentionally for stylistic choices (a measure of creativity). A key take-away message for the artistic community is that adoption of Multi-View Sighting and related interfaces can lead to closer observation and the translation of those observations into more accurate drawings.

There are two main take-away messages for the AR/MR research community. First, more research is needed on Drawing From Life, *observation-focused* 3D drawing, which is different and far more challenging than tracing a reference. While tracing, scanning, and related (semi-)automated approaches (discussed in Section 2.1) are good for accurate geometric reconstructions, Drawing From Life specifically targets observation with your own eyes which allows a level of interpretation and critical thought. More interface development is needed to augment or train human perceptual skills.

Secondly, the research community should consider using more holistic, in-the-wild evaluations like the semester-long field deployments. Across all areas of AR/MR research, Merino et al. [37] urge researchers to conduct real-world case studies to improve ecological validity of AR interfaces more generally, noting that only 13% of their surveyed AR studies were conducted "in-the-wild." Specific to 3D drawing in VR/AR/MR, Machuca et al. [34] point out the current lack of field deployments and call for comprehensive long-term evaluations of 3D sketching. Combined, our evaluations over the two semesters show: 1. acquired skill and expected performance from users trained in 3D drawing over a 15-week semester; 2. qualitative, quantitative, and visual results from multiple classroom activities in a second semester. A carefully controlled lab study would have been less effort to conduct and easier to report and interpret, but it is impossible for a lab study with novices to generate the example drawings and experiences from trained experts contributed in this paper.

5 Conclusion and Future Work

This paper contributes technical advances in the form of novel 3D user interface along with example drawings, data, and analysis from a field deployment with students. This work is significant because, to our knowledge, it is the first in 25+ years of 3D drawing research that combines 3D drawing with user interfaces designed specifically to support real-world observations. Students' work and feedback demonstrate qualitatively and quantitatively the positive impact this can have on creative 3D drawing workflows that aim for accurate proportion without sacrificing freedom of expression.

Our future work includes expanding the framework to support observing additional features of interest to artists, for example, angles and negative space. We also plan to continue to deploy the new tools in courses and other real-world contexts beyond art and figure drawing. We are deeply motivated by the way traditional drawing is taught, where *learning to see* is the key to learning to draw, and we hope to uncover through future longitudinal studies what specifically 3D drawers learn through the act of drawing from observation in mixed and augmented reality.

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