Drawing with bare hands: a hand-gesture based drawing experience with motion sensors.

Alekos Diacodimitri[1], Federico Rebecchini[1]

[1] Department of Department of History, Representation and Restoration of Architecture, Sapienza University of Rome, Rome, Italy
alekos.diacodimitri@uniroma1.it; federico.rebecchini@uniroma1.it

Abstract. One of the features that makes analog drawing so fascinating is its manual component. The path of a graphite line on the sheet, the different pressure of the stroke, the texture described by an entropic movement, the unexpected residues of dirt, each of these things virtually refers to the intervention of a hand. This research unfolds around the idea of using the movement and gestures of the hands as a basis for the generation of forms for architectural design. Not three-dimensional models, but flat shapes, two-dimensional digital drawings generated by the author's gestures. Through a Leap Motion sensor and a digital drawing program, all the various forms of freehand drawing were explored, finding an interesting result in the field of free shape generation linked to hand gestures. The result of this experience is a different way of seeing gestures as a generative tool of architectural forms, to be used into architectural design process.

Keywords: Media art, Digital drawing, Shape generation, Gesture, Motion sensors

1 Introduction

The definition "Architectural Representation" includes within it a varied spectrum of graphic outputs. We can include study sketches, definitive drawings, CAD-produced designs, photorealistic renderings, architectural photographs, and any type of output representing a built or unbuilt architectural space. Within this paper architectural representation has been approached with a very specific approach. Among the many paths of representation, the one that has been traveled starts from the most classical premises: a hand holding an object designed to depict something. A stick on the ground or a pencil on a sheet of paper, there is little difference in the moment when the protagonists of the action lead to the same result, albeit with different graphic style: the description of a space.

Hand drawing was for hundreds of years the only tool that architects had at their disposal to control often insurmountable complexity. The continuous refinement of drawing techniques led in the late 1900s to a quality in analog representation that has never been equaled. The advent of digital drawing, from CAD to its evolutions in terms of 3-D modeling, have slowly widened the mesh of architectural representation leading to an inflation in terms of styles and quality, expanding a field that to this day is trying to find margins that are getting further and further apart. Within this situation a permanent center of gravity is represented by analog hand drawing. It, though often relegated to the background within the most avant-garde faculties of architecture, continues to maintain unchanged its status as the primal locus of architecture's development and eventual study. Sketching allows an immediacy in recording data that digital still fails to provide. In addition, hand drawing possesses something that digital can never even simulate, and that is gesturality. In it often lies the fascination with analog drawing. The way a pencil is gripped, how its tip comes into contact with the sheet of paper, the pressure of the tip on the roughness of the support, and finally the actual gesture of the performer of the drawing, which between muscle memory and creative darting produces strokes impossible to simulate (Fig. 1).

For who is writing beginning with gestures in representation was therefore a due act, if not the only one possible when approaching drawing. The hand is the performer of the gesture, an irreplaceable appendage that allows one to better control spaces and directions previously only imagined. A human hand is subject to error and contradictions. The gestures of our hands are at the basis of creation through drawing: in order to create they are always in contact with the instrument that mediates our thinking. We inevitably pass from some object (pencil, pen, nib, brush, digital pen, mouse, VR controller) to an output. Each of these instruments interprets the gestures of the hands through their own peculiarities. This consideration introduces the possibilities of gestures in the digital realm as well. Some tools such as CAD software do not provide for it, but new technologies are increasingly moving in this direction. The possibility of interacting in digital environments through tools that detect our gestures is becoming more and more essential year by year for hardware manufacturers and not only. Digital giants such as Meta (formerly Facebook) and their Oculus virtual reality headset are granting increasing space to the enjoyment of their devices through simple hand movements. Gestures, in the specific the motion tracking technology, thus become a tool to humanize and make less mechanical operations limited to the digital environment, with mixed results that not infrequently make one regret the classic mouse and keyboard.

At this point the question that arises is: is gestural drawing something easily translatable into the digital environment? Is analog manual dexterity necessarily the starting point, or at least the ambition, of image production in the digital environment?

This study, starting from the assumptions of the Doctoral Thesis of one of the two authors, unfolds trying to answer these questions, starting from the reduction of the parts involved: it is only the hands that generate the signs. The drawing then becomes bare-handed.

Figure 1. Sketches of architectures from the Ostiense Area in Rome. These sketches were produced in less than 3 minutes each. They are the study sketches produced in order to capture the mood and architectural qualitites of a specific area of Rome. Source: Drawings by F. Rebecchini, 2022.

2 Methodology

2.1 Hardware and Software

Motion tracking systems allow the quantitative study of human body motion. With them it is possible, for example, to calculate the angle between two body segments, the position of a body's center of gravity, or the distribution of forces in the limbs. Originating in the medical field for the study of the pathophysiology of the musculoskeletal system, they now find application in numerous fields, from the design of medical prostheses to sports analysis, to digital animation in film and video games, to virtual reality applications REF.

In this study focused on motion capture graphics, a LEAP motion and a digital painting software were used.

LEAP motion is an optical markerless tracking device produced by the American company Leap Motion Inc. and has been on the market since May 2013, the development of which began in 2008. It is, essentially, a device through which it is possible to interface with a computer by tracking the user's hands. The LEAP motion can track the finger movements of both user’s hands, going so far as to define the position of the individual phalanges of each finger, with a claimed accuracy of 0.01 mm. It is a small USB peripheral that is designed to be placed, facing upward, on a desk between the user and the computer screen. With the presence of two cameras and three infrared LEDs, it can map an approximately hemisphere-shaped area about one meter in diameter. The LEAP software analyzes the objects observed in the device's field of view, recognizing hands, fingers, and any tools being used, while simultaneously reconstructing their position, gestures, and movements.

Corel Painter Freestyle is a graphics software developed by Corel Corporation. It is a version of the more famous Corel Painter program specially designed to work with LEAP motion. The classic version of the software is used to create artistic images by digitally simulating certain painting techniques: Interfacing with the computer via a graphics tablet, the user can create remarkably realistic images by drawing freehand, thanks to the software's opportunity to simulate a wide selection of classic effects such as watercolor, gouache, oil painting, and many others. In its Freestyle version, this software keeps intact the philosophy behind the classic version about the simulative approach to physical painting and expands the possibilities by allowing the user to relate to the program via LEAP motion.

Today, the software has ended its beta testing phase and is no longer currently available to the public in any form.

2.2 First applications of drawing

In the first phase of the study, our goal was mimesis. We wanted to obtain graphic designs that mimicked the results obtainable from other techniques, whether traditional or digital. By exploiting LEAP motion to process different types of drawings, we came to be able to estimate its effectiveness, its distinctive features, as well as its inevitable criticalities. No attempt was made to elaborate a theory to be later applied to practice: on the contrary, it was the practice itself, experimenting with different graphic solutions, that generated its corresponding theoretical apparatus as a logical consequence of trial and error.

At this stage, our study was developed to recreate the experience of drawing from life that takes place in close contact with architecture, and which has its origin in the architect's notebook and in their ability to analyze buildings through freehand drawing (see also Fig. 1) (Chiavoni, Docci, 2017). An attempt was made to try a similar experience by replacing the classic notebook with a laptop computer coupled with a LEAP motion and using a wooden stick as a virtual drawing tool, emulating real drawing gestures. The real-life drawing experience was conducted using a type of line drawing, thanks to one of the digital graphic tools made available by Corel Painter Freestyle, which simulates the characteristic strokes of graphite and marker pen, configured in such a way as to match variations in hand distance from the screen to the intensity of the mark.

This experience of drawing from life showed all the limitations of instrumental accuracy of LEAP motion: the line drawing is particularly uncertain and shaky. Attempting to reconstruct, for example, the elevation alignments of windows is virtually impossible: the result is a series of flickering, overlapping horizontal lines that are, in the end, meaningless (Fig. 2).

Figure 2. Shaky drawings produced with the aid of wooden stick. The stick was motion tracked by the LEAP Motion. Source: Drawings by A. Diacodimitri on Corel Painter Freestyle, 2016.

2.3 Instrumental accuracy

The degree of instrumental accuracy of LEAP motion has been the focus of several studies, which have established through experimental data its level of reliability. A study (Guna et al., 2014) tested through various procedures the degree of reliability of LEAP motion. A set of static and dynamic measurements was prepared with different tracked objects and varying configurations. For static measurements, a plastic model of a human arm was used, while for dynamic measurements, a special V-shaped instrument simulating two fingers placed at a fixed distance from each other was made. In static measurements, the standard deviation was measured as less than 0.5 mm. Furthermore, this value was shown to increase as the distance of the object tracked by the sensor increased. The results of dynamic measurements revealed poor performance, with a collapse in accuracy for greater distances from the sensor. The conclusions of the research team indicate that:

"The Leap Motion Controller undoubtedly represents a revolutionary input device for gesture-based human-computer interaction. In this study, we evaluated the controller as a possible replacement for a fast and high-precision optical motion capture system in a limited space and with a limited number of objects. Based on the current results and the overall experience, we conclude that the controller in its current state could not be used as a professional tracking system, primarily due to its rather limited sensory space and inconsistent sampling frequency." (Guna et al., 2014)

2.4 The instrumental error betweencontrol and randomness

In addition to aspects related to instrumental accuracy, the main instrumental error issue concerns shadow cones that are created during finger movement and are referred to as occlusion phenomena. The management of the error related to occlusions is crucial for this study, since, as will be seen, the phenomenon actively participates as a semi casual component in the generation of free form. This phenomenon, by its very nature not eliminable, is generated at the very moment when, during the movement of the fingers of one hand, one finger covers another finger relative to the position of the controller that is tracking its movement. In the short period of time in which this phenomenon occurs, the sensor "loses sight" of the finger, which consequently disappears from the relevant frame, only to reappear again in the next frame, but no longer belonging to the previously traced motion, becoming the starting point of a new motion. This occlusion has strong consequences in terms of the graphic result, since all the shapes that are generated with these procedures will present obvious points of discontinuity, as will be better seen in the paragraphs on the experiences of generating simple and complex shapes, causing on the one hand great difficulties in handling the shape, and on the other hand unpredictable graphic peculiarities worthy of interest. Generally, these occlusions tend to occur more frequently when the hand makes rotational movements.

2.5 Two-dimensional free-form generation

All the described instrumental errors led to the unsatisfactory results described in the section 2.2. This brought to the formulation of a new research path, focusing on the generation of free forms associated with hand gestures. These forms can become tools for architectural design research.

The initial phase of the design process in architecture plays a key role within the compositional process. During this stage, drawings are made so to act within that moment in which the conceptual and spatial complexity of the project is formalized through a quick, jet-like, and (almost always) freehand drawing. The nature of such sketches, from a graphic point of view, is characterized by a very strong level of ambiguity; the meaning of the single sign does not yet have those characteristics of univocity proper to the final drawing, but rather, has precisely in the interpretive variables its greatest strength. The idea is hinted at, is beginning to take shape and will later find substance precisely in its unfolding and unraveling in successive stratifications. In this view, the instrumental imprecision of the analog medium (the pencil, the marker, the paper) plays a fundamental role. In employing these instruments, we take part to a phase of partial randomness, in a still not totally controlled environment that can produce results that are still unexpected. These results almost always require numerous successive iterations before finally coming to fruition.

Instrumental errors, which in other areas have, as we have seen, yielded unsatisfactory results, can here be transformed into a positive quality. At this stage of the study, we focused on investigating the ways in which a free form can be generated through LEAP motion, to understand how controllable this is, how it can be interpreted, and in what ways different movements in hand space

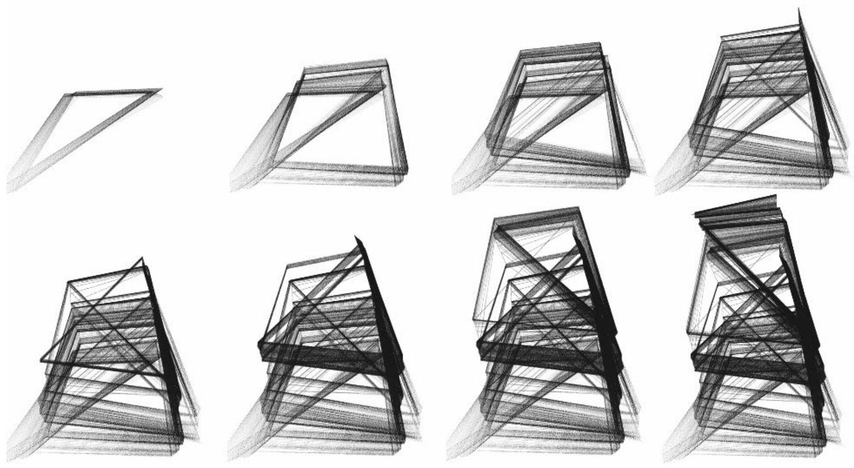

Figure 3. Hand-tracked movements describing a pseudo-axonometric construction.
Source: Drawings by A. Diacodimitri on Corel Painter Freestyle, 2016.

are associated with designs that have recurring peculiarities. Within the working environment of Corel Painter Freestyle software, it is possible to act on brush control parameters such as minimum and maximum painting depth, finger spacing, tilt control, and most importantly, it is possible to enable multiple inputs, with 1 or 2 degrees of connection between individual inputs. These possibilities offered by the software make it possible to achieve special graphic results, since they allow several fingers at the same time to collaborate in the realization of the drawing, by tracking the whole opened hand. As a result, compared to single-input operations, the movements that the hand must make are much more organic and complex. This has led to the development of a peculiar graphic language made up of simple 2, 3 and 4-input movements such as translations and rotations, which generate two-dimensional shapes that tend to recur. These forms thus generated were then classified according to the type of gesture that generated them.

When the fingers are made to make movements parallel to each other, a movement is composed, which is here called translation, and which generates simple forms. Such forms develop, of course, according to a single direction. In this case, occlusion phenomena are limited since the fingers all move according to a single direction and thus tend to avoid overlapping one another. This generates shapes that perceptually resemble pseudo axonometric constructions of extrusions along the direction of hand movement (Fig. 3).

By rotating the wrist during hand tracking, the fingers make a rotational movement that graphically transforms into a complex shape. This shape is particularly difficult to read, as the marks tend to overlap without having a chance to develop along a prevailing direction. For this reason, it was preferred to replace the simple rotation movement, which is particularly unmanageable,

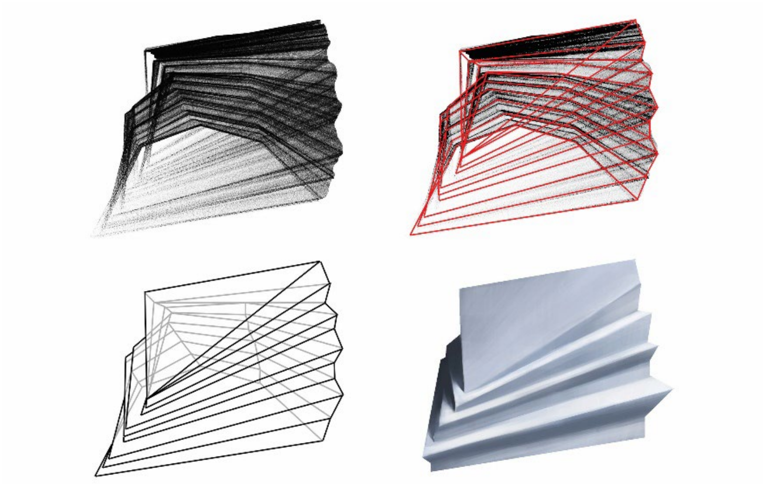

Figure 4. Interpretive process of a form produced by a translation gesture. Source: Elaboration by A. Diacodimitri on Corel Painter Freestyle, 2016.

with a roto translation movement, thus combining the rotation with a linear movement of the whole arm along one direction. In this case the phenomenon of occlusion is particularly present, since at the moment of rotation the fingers tend to create shadow cones and cover each other with respect to the position of the sensor. It has been noted how roto translation movements generate shapes that perceptually recall perspective compositions, probably by virtue of their extreme chaotic nature, within which it is difficult to recognize lines parallel to each other. To this was then added a "modifier gesture," which can be used in both cases, namely finger opening. This distinction between simple and complex forms stems fundamentally from the level of "noise" that the movement generates, caused by the phenomenon of mutual occlusion that is formed between the fingers at the time the gesture itself is performed. As occlusions increase, noise increases and consequently the user's ability to control and manage the form decreases.

This experience can be said to straddle the influences from action painting and those from generative art. Of the former it retains the gestures, the active participation of the body and the transformation of a movement into a representation; with the latter it retains an assonance of results in graphic terms and the fact that the machine, with its errors and imperfections, participates in no small part in the elaboration, although not to the same extent as in generative art.

3 Results

3.1 Interpretation of shapes

It has been said that the shapes elaborated so far undergo a perceptual process by which they are associated with a determined method of representation, although in reality they do not actually respond to any geometrical rules or graphic constructions other than those precedingly described relating to the movements that generated them.

However, indeed, when one observes a shape generated by a translation, it comes naturally to relate it by analysis to an axonometric projection. The reason why this perceptual phenomenon is to be found in several factors. The first factor can be found in the fact that the surfaces that are formed are not graphically pre-sensed as homogeneous and continuous surfaces due to a lag in reception, so a kind of "frame effect" is generated. It allows the entire construction to be seen in transparency and allows all the horizontal sections present on the form to be distinguished. (Fig. 4)

Finally, we must add the component related to the parallelism of the lines: during the translation of the fingers, we obviously tend to keep each finger on a direction vector that (unless there are finger openings) turns out to be always parallel to that of each other finger, because these fingers belong to the same hand. These parallelisms contribute substantially to the perception of the shape as axonometric.

These works remain, as mentioned above, pure suggestions, useful mainly for the advancement of a strongly abstract graphic experimentation. It turns out to be interesting, in this perspective, the component of elaboration linked to the strong randomness of the gesture: in the sphere of artistic expression, the reconnection of such procedures to some aspects of action painting leads to obtaining new and previously not so easily achievable forms. And it is precisely on this principle of "immediacy" of generation that experimentation gains value, aiming at the recognition of gesture and form and free pictorial reinterpretation.

In contrast to what happens with simple forms, where edges and surfaces are clearly visible and exclusively need critical reading, interpretation, and selection; in complex forms this possibility is absent: layered lines, overlaps, intersections and occlusion imperfections are present in such quantity not allowing what in the interpretative process of the simple form took place in the early stages of "polishing" the predominant marks.

3.2 Digital painting over the shapes

By virtue of this, an experimental experience is proposed here that is analogous to the preceding ones in technique but very different in approach, path, and its conclusions, going back to the basic form to a real object that has an extremely elastic connection with that form. Similar to that which a designed architecture may have with one of the first concept sketches that generated it.

Clearly, this implies that the discretionary aspect takes over any kind of analysis in this case: one does not identify lines, surfaces, but rather mass, solid/void ratio and intensity of sign, with the only obligation being to identify each part as being part of a coherent overall perspective representation as far as it can be interpreted.

The initial form worked on Fig. 5 is deliberately extremely complex: it was generated by two particularly articulated rototranslational movements accompanied by a series of finger openings and closings. This shape is first straightened, in order to be able to identify a plausible horizon line and then interpreted as a shape in its entirety. Unlike in the other cases, where the painting operations are "supplementary" to the sign, here the digital pigment becomes preponderant over the original form, and already in the early stages it is possible to see how free the interpreting of the signs is, and how some of them, despite their graphic strength, are not taken into consideration, as they are considered inconsistent with the form that is taking shape. In the subsequent stages, the forms continue to define themselves, seeking a plausible spatial validity: the main triangular forms are configured as covering architectural elements, retaining the spatiality and lines of force of the original form, while other elements are built up for formal coherence until the final elaboration is obtained. Clearly, the representation obtained during this study cannot be defined as a fully designed architecture: too many fundamental elements of the traditional design process are missing to be able to define such forms as architecture, both aesthetically and functionally, constructively and in relation to the context.

3.3 Conclusions

What in the original intentions would have made the difference within this path would have been the variation, induced by the atypicality of the instrument, of the gestuality of the act of drawing.

Almost immediately, these original intentions were contradicted, overturned by the evolution of experimentation, by the realization of the actual potential of these instruments, but also by the instrumental limitations encountered, by the problems that emerged over time, and, why not, by a personal sensibility that led to favoring some solutions at the expense of others, probably just as valid.

The LEAP motion is undoubtedly a valid instrument, fascinating in some ways and with great potential, yet it presents a whole series of problems related to instrumental precision that in fact could easily dilute any easy enthusiasm, especially if one takes into account the fact that, according to its producers, its extraordinary precision should be its workhorse.

Paradoxically, what it should do best, namely the precision design, becomes what it does worst.

In the area of form generation, there are numerous possibilities that new technologies offer, such as parametric modeling; yet, it is precisely here that one can see the decidedly atypical potential of LEAP motion compared to other,

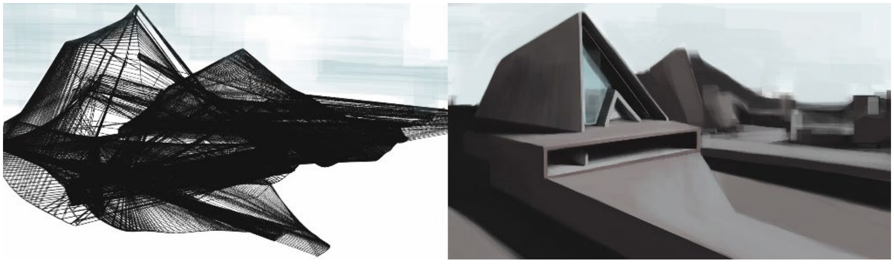

Figure 5. Digital painting over a free form. Source: Elaboration by A. Diacodimitri on Corel Painter Freestyle and Adobe Photoshop, 2016.

more widely used tools: first of all, the figure of the human being, which is "physically" central to the process (and thus not only on an intellectual level), as well as a newfound starring role of drawing as a pure graphic expression of an intention.

The correspondence found between hand gesture and graphic result has in itself a value that relates directly to drawing understood as a material act that performs a certain mental process, thus returning in a sense to the true roots of drawing for design.

Certainly, the results that are obtained with these experimentations are unique, difficult to replicate with other tools (and certainly not with the same immediacy). But their evocative component is still prevalent, especially because of certain cumbersomeness in the process of rationalizing forms.

Further investigation, from a more purely geometric point of view, will be necessary regarding the modalities with which these forms are spatially interpreted, perhaps trying to reconstruct different projection centers that return different patterns of the same projection, in order to hypothesize whether there are some that we are inclined to exclude because they are considered implausible. Precisely the perceptual aspect, which has been addressed here exclusively as a function of the study of the properties of the final products that can be obtained from the two-dimensional forms generated with movement, may become an even more fundamental element of the research, thus necessitating a more reasoned, rigorous, and complete investigation.

4 Discussion

Something as personal and vibrant as the gesture has become the new territory to be colonized by giant technology corporations. Our gestures are increasingly adapted to the tools we are led to purchase, and understanding our movement is just one more attempt to make us familiar with very often unnecessary devices. The example of the Oculus visor from the aforementioned Meta is illustrative in this regard. It is a hardware that has been constantly implemented (Buckingham, 2021) despite the inevitable problems related to hand tracking (Abdlkarim, …, 2022). The company's CEO Mark Zuckenberg envisions a future where, wearing our headsets, we can meet and work in the Metaverse. Still, everything seems to be extremely vague (Broderick 2022-1). What is implicit is the humanization of a digital space, populated by avatars, that promises endless possibilities. The actual need and usefulness of these digital spaces is all to be proven (Broderick 2022-2), but what this research tries to express is how very often tools born for a certain intent take on completely new connotations.

Experimentation in the field of drawing thus becomes a case study scalable to even very different disciplinary fields. The search for a known and familiar gesture in a novel environment brings to the surface criticalities that are often hidden. Only by changing the point of view, following a trial & error that leads to greater understanding, is it possible to fully understand the possibilities of a tool. What was created for an intent finds through experimentation a new method of expression.

Through the exploration of the possibilities of drawing with bare hands, it is possible to understand how a different gesture, always the result of the human hand, becomes the key to new discoveries. The digital environments in which we will soon move will, hopefully, also find in human gesture a point of reference.

References

Guna, J., Grega, J., Pogačnik, M., Tomažič, S., Sodnik, J. (2014). An Analysis of the Precision and Reliability of the Leap Motion Sensor and Its Suitability for Static and Dynamic Tracking. Sensors, 14, 3702-3720. https://www.mdpi.com/1424-8220/14/2/3702

Buckingham, G. (2021). Hand Tracking for Immersive Virtual Reality: Opportunities and Challenges. Frontiers in Virtual Reality, October 2021, Volume 2, Article 728461, 6 pp. https://doi.org/10.3389/frvir.2021.728461

Abdlkarim D., Di Luca, M., Aves, P., Yeo, S.H., Miall R.C., Holland, P., Galea J.M. (2022). A Methodological Framework to Assess the Accuracy of Virtual Reality Hand-Tracking Systems. A case study with the Oculus Quest 2. Preprint bioRxiv. https://doi.org/10.1101/2022.02.18.481001

Broderick, R. (2022-1). A New World of Cronut Lines. Garbage Day. Retrieved June 28, 2022, from https://www.garbageday.email/p/a-new-world-of-cronut-lines

Broderick, R. (2022-2). You Don't Need a House in the Metaverse. Garbage Day. Retrieved June 28, 2022, from https://www.garbageday.email/p/you-dont-need-a-house-in-the-metaverse

Bingham, N. (2013). 100 Years of Architectural Drawing. Laurence King Publishing.

Chiavoni, E., Docci, M. (2017). Saper leggere l'architettura. Laterza.