Between Technical Realization and Creative Process: The Interdisciplinary Development of Augmented Reality Art at the AURORA School for ARtists

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Abstract

From 2018 to 2021, the EU-funded project *AURORA School for ARtists* at the University for Applied Sciences (HTW) Berlin offers artists and other creative freelancers a wide range of training courses on Augmented Reality (AR), workplaces equipped with hard- and software (at least until 2020), as well as support by AR specialists to digitally expand their analog works. How can such a project succeed? How far can artists go together with their tutors to implement their concepts and where do they reach limits? Finally, to which conclusions does the experience in the AURORA training for arts and culture professionals lead? The paper will provide information with a focus on the development of artistic AR applications as an interplay between technical feasibility and creative process.

Introduction

The use of mobile augmented reality (AR) in art celebrated its tenth anniversary in 2020: with the market launch of AR-compatible smartphones in 2009, artists who discovered this technology as a new medium have been appearing since 2010. Among them were Tamiko Thiel and Mark Skwarek, who were to be among the founding members of the first AR artists' group *Manifest.AR* in 2011. The first mobile AR art was politically engaged: with actions such as logo hacking in public space and an AR guerilla intervention at MoMA New York, it drew attention to violations such as environmental catastrophes and to the established art canon (see Skwarek 2018). The expectation formulated by Jung Yeon Ma and Jong Soo Choi in 2007, that AR would prove valuable for artistic applications, came true in artistic practice shortly afterwards (see Jung/Jong 2007). Meanwhile, AR no longer needs guerrilla actions to get into art and cultural institutions: most institutions that want to keep pace with digital innovations have AR in their repertoire, whether in the form of AR art, of mixed reality installations and performances, or for education purposes or as guidance systems.[1]

AR software and platforms today offer more possibilities than they did ten years ago. But to achieve individual results of high quality, an extensive knowledge of digital media production and programming often is necessary. There is a tendency towards interdisciplinary cooperation between cultural institutions or established artists and computer scientists – assuming the appropriate budget is available. This is normally not the case with freelance arts and culture professionals who are interested in using AR to expand their work. To counter this, the EU-funded *AURORA School for ARtists* at the HTW Berlin offers training courses on AR where freelance arts and culture professionals can learn the basics of the technology themselves. The HTW project also provides an AR production laboratory, where artistic AR applications can be implemented with support by experts of the project team. As a pioneer project in Germany, the *AURORA School for ARtists* has transformed into a think-tank for arts and AR, where technical realization and creative processes go hand in hand.

The paper begins with a brief overview of the HTW project's starting point by focusing on the technology's state of the art, the current situation in Germany's independent art scene and existing courses on AR at art academies in Germany and beyond. It then directs attention to the interdisciplinary development of artistic AR applications in the AURORA production laboratory, leading to conclusive reflections on the artistic training in this technology that is predestined to merge the analog with the virtual reality.

Augmented Reality – The Point(s) of Departure
The state of the art

While many early AR applications have been developed from scratch, the current trend is to build AR apps using traditional game engines like Unity or Unreal Engine. Unity claims that 60% of all AR/VR apps are powered by its engine (see Unity Technologies 2018). Using game engines makes sense, as they already provide most of the components necessary for creating immersive 3D worlds, e.g. graphics rendering, audio, video playback and physics, enabling creators to quickly develop AR prototypes.

Until recently, most AR software used visual markers to anchor virtual objects in the physical world. Using algorithms from the domain of computer vision, natural features (e.g. corners) are detected in a reference image. The algorithms then continuously search for such feature patterns in the camera stream of a mobile device to detect and track the occurrence, position and orientation of the reference image in order to place the virtual content (see Park et al. 2005). Multiple vendors like *Vuforia* or *Wikitude* provide such algorithms as includable libraries, which can be used in game engines to provide the image tracking capability of AR apps.

With the advent of Apple's ARKit (2017) and Google's ARCore (2018) it is now also possible to place virtual content anywhere in the environment without the need for visual markers. Users can walk freely, while virtual objects are stably positioned in the physical world.
The technology behind this, called visual-inertial odometry, continuously maps the environment and keeps track of the device's position and orientation within this map by analysing consecutive camera images (see Li/Mourikis 2013). Unfortunately, Apple and Google develop their libraries ARKit and ARCore only for mobile devices. Thus, it is currently very complicated to search for bugs in ARKit/ARCore applications in a game engine editor on a PC.

Besides smartphones and tablets, consumer AR glasses like the *Microsoft HoloLens* or the *MagicLeap* have been available since 2016, albeit for high prices. AR glasses have the advantage of placing virtual content directly into the user's view without a noticeable screen between them and the environment, thus creating a stronger sense of immersion (see Bach et al. 2017). Because the hands have been freed from holding a mobile device, AR glasses also support more intuitive interaction using hand gesture recognition (see Microsoft Corporation 2020). One of the main drawbacks of the current generation of AR glasses is a limited field of view, resulting in virtual objects being visually cut off (see Bach et al. 2017).

To ease the development for different devices, in 2018 Unity started to develop its own library, ARFoundation, which hides the implementation details of ARKit, ARCore, MixedRealityToolkit (*HoloLens*) and the Lumin SDK (*MagicLeap*) behind a shared API and user interface (see Weiers/Durand 2018). ARFoundation provides image tracking and visual odometry. Due to the limitations of ARKit and ARCore, specific mobile devices are necessary for testing, which increases hardware costs and slows down the practical exercises. That is why ARFoundation is only used in the AURORA production laboratory, but not in the workshops.
The near future will bring at least two crucial enhancements for AR software. First, various companies like Google and Facebook are currently developing visual positioning services, which allow to track user positions and orientations far more accurately than GPS – indoors and outdoors – and as such making location-based AR more feasible (see Reinhardt 2019; O'Hear 2020). Second, the continuous effort of the World Wide Web Consortium to specify WebXR will soon bring AR to (mobile) browsers. This has the grand advantage that users don't need to install AR applications on their devices and in turn lowers the entry barriers (see Bozorgzadeh 2018).

The situation in Germany's art scene

When the AURORA project started in April 2018, there were already several stakeholders in Germany's art scene working with AR as an artistic tool or giving it a public platform. Successful digital artists such as Tamiko Thiel and the duo Banz & Bowinkel attracted Germany's art scene's attention to AR as a futuristic artistic medium adding a digital layer to our physical world. The tool has a high potential not only for the democratization of the art world (see Thiel 2018), but also for the exploration of questions arising with technological innovation in the field of a seamless combination of the analog and the digital world in a Mixed or

even Hyper Reality.[2] Respect is due to AR pioneers, who had to educate themselves in the complex technology: before 2018 there were no further education offers for artists in AR. But there have been several curators supporting and exhibiting digital art forms such as Virtual Reality (VR) and AR: Wolf Lieser has regularly shown AR and VR artwork in his DAM projects[3] in Berlin that emerged from the Digital Art Museum (DAM) – one of the first galleries to establish digital art on the market –, e.g. by Carla Gannis in 2017 and Banz & Bowinkel in 2019. Tina Sauerländer, Peggy Schoenegge and colleagues run the platform *peer to space* focusing on AR and VR artwork and exhibitions. Together with Philip Hausmeier, Tina Sauerländer is also is the cofounder of *Radiance*, the research platform and database for VR experiences in the visual arts, which includes some AR art made for the AR glasses *HoloLens*.[4]

Since 2017, the AR tool *Artivive* has been offering artists the opportunity to easily augment their work with digital images and videos.[5] In 2019, *Adobe* also published its own AR platform *Adobe Aero.* Providing combinable algorithms such as "walk" or "jump", it lets you determine the behavior of uploaded digital content (such as 3D models) to a certain extent.[6] The more individual results such intuitive tools allow, the more artists will work with them autonomously. But the digital content still has to be produced separately or prefabricated assets must be used.

In the field of events, festivals such as the *VRHAM!* in Hamburg and the *Virtual Worlds Festival* in Munich were launched in 2018 and 2019, awarding prizes for immersive art experiences.[7]

In 2018, AR art also arrived in established German museums: an exhibition on *Mixed Realities* took place in the Kunstmuseum Stuttgart, exploring how artists deal with this new setting of realities by using the corresponding technologies.[8] But the exhibition in Stuttgart also revealed new challenges in terms of presentation: how to exhibit AR art in such a way that visitors understand what needs to be done? In *Mixed Realities*, many visitors just ignored the tablet on a socket that was meant to augment the art of Tim Berresheim. The Kunsthalle München of the Hypo-Kulturstiftung and the Ludwig Forum für Internationale Kunst in Aachen presented an exhibition with the title *Lust der Täuschung – Von der Antike bis zur Virtual Reality* in 2018/19 (see Beitin/Diederen 2018).

A quite new phenomenon is the English high-profile company *Acute Art*, directed by the curator Daniel Birnbaum since 2019: *Acute Art* invites renowned international artists like Marina Abramović or Jeff Koons to cooperate with them in order to produce elaborate XR artworks. Some of them were shown in the Julia Stoschek Collection Berlin in 2019/20,[9] which emphasized the importance of EU-funded projects like AURORA in order to provide support also to the independent art scene and subcultural low budget projects.

In 2020, the coronavirus led to a rapid increase in digitization, which in turn gave impetus to an impressive variety of new experimental digital art approaches in Germany – e.g. the project *unreal.theatre* (funded by the German Kulturstiftung des Bundes) where performing artists interact in the social space *VRChat*, which was originally developed for VR gamers.[10] Meanwhile, the project IN VR WE TRUST brings a critical point of view to the reception of VR art.[11] In the AR field, the NRW Forum Düsseldorf together with the Kunstpalast announced the first German AR Biennale,[12] and the *AURORA School for ARtists* plans a final exhibition – both are planned for autumn 2021. Not least, Covid-19 has enhanced public arts and culture funding on digital formats. As a result, we may expect many more exciting AR art experiences in the near future.

Augmented and Virtual Reality in artistic education

As you might have noticed in the previous chapter, VR and AR technologies are often presented and thought of together. On the one hand, the experience and the applied hardware are still quite different: Whereas VR allows total immersion into the virtual world, AR still lets you perceive the analog world. AR applications are usually developed for smartphones and tablets (AR glasses such as the *HoloLens* are very expensive) – for VR applications you need VR glasses or at least a cardboard box in combination with a high-end smartphone. As a result, there are strong conceptual differences. On the other hand, in theory they are both part

of the *Reality-Virtuality-Continuum* by Milgram and Kishino (1994) – and there are also similarities in the practice: As both technologies rely on game engines such as Unity, especially from the developer's point of view they are 95% similar.[13] Furthermore, AR and VR glasses will one day merge in one Mixed Reality hardware: The *HoloLens* gets an ever-larger field of view and better color coverage to overlay the analog world, while VR glasses now have integrated cameras to include the outside world. Thus, especially in the field of application development, not only separate but also combined AR and VR courses make sense.

AR and VR first had to prove themselves as serious artistic media before being accepted into teaching at art academies. There are various courses at US American art academies, such as the School of Visual Arts New York, the Columbia College Chicago or the Hunter University of New York.[14] In Europe, more and more institutions such as the London College of Communication offer courses or master's degrees of Design in both AR and VR.[15]

Even though there was no AR/VR professorship at German art academies in 2019/20, we observe more and more talks, seminars and workshops on both technologies. To mention a few examples, the Hochschule für Bildende Künste Hamburg offered a lecture series on *VR und AR und Immersion in der aktuellen Kunst- und Designproduktion* during the winter semester 2019/20.[16] At the Academy of Media Arts (KHM) in Cologne, students experiment with the technologies within their student's projects and expand creative projects such as exhibition posters with AR. They are supported by the professors Melissa de Raaf, Zil Lilas and Tania de Leon Yong. In order to provide technical and curatorial support for their students, they plan new partnerships with other institutions and museums. The Burg Giebichenstein in Halle offers a study program named *Multimedia | VR Design* (B.A.).[17] At the HTW Berlin, the research group INKA works in the field of AR and VR for the art and culture sector offering also student's projects.[18] In the field of computer science, the study program *Informatik in Kultur und Gesundheit* will start at 1 October 2021 at the HTW Berlin, offering one course on Mixed Reality. Students of communication design could attend Pablo Dornhege's semester program *Zwischenwelten – Schnittstellen zwischen Virtual Reality und physischer* Welt in 2019/20.

Seen from an institutional perspective, design disciplines are slightly more open for interdisciplinary XR studies than the traditional arts, and media art academies as well as universities of applied sciences involve XR technologies more rapidly in their curriculum than traditional art academies. What might be the reasons for this? In addition to their stronger focus on new technologies, there are also some parallels between the UI and the logic of digital media production software – such as After Effects, Blender or Premiere – and the Unity editor. As we could also observe in the AURORA workshops, the entry barrier for professionals of digital media production to *Unity* is lower than for analog artists such as painters or authors. Another advantage for designers and media artists: They can use their individual digital media – such as 2D and 3D models or animations – for the AR layer. Not least and as explained above, with ARKit and ARCore you can place virtual content anywhere in the environment without the need for visual markers – which means that digital media artists don't even necessarily need an analog artwork to show their digital art in AR. As a consequence, the implementation of XR course and study programs at educational institutions offering media production courses absolutely makes sense. But what about interested arts and culture professionals who cannot benefit from these seminars or (upcoming) study programs?

Closing the Gap: The AURORA School for Artists

AURORA is a project of the INKA research group led by Prof. Jürgen Sieck at the HTW Berlin. Before the project started in April 2018, there had been no training program about AR tailored to the needs of arts and culture professionals in Germany. Especially in this area of training for freelancers in Berlin – forming the target group due to EU funding –, the project came at the right time and could definitively close an important gap in Germany's art landscape. From the beginning of the project until the end of 2020, the *AURORA School for ARtists* at the HTW Berlin counted 485 participants in its AR workshops and talks. Most participants were visual artists – but the events have also been attended by authors, performing artists, illustrators and designers. So far, 17 individual AR applications have been implemented in the production laboratory. In close one-to-one-cooperation with the project's AR and media production experts they have been realized by the following artists: Banz & Bowinkel (multimedia art), Annagul Beschareti (fine art), Phyllis Josephine (multimedia art), Olga Lang (literature) & Julia Laube (performing arts), Bianca Kennedy (multimedia art), Sarah Müller (design), Dani Ploeger (multimedia art), Theresa Reiwer (performing arts), Peter

Sandhaus (sculpture), Dagmar Schürrer (multimedia art), Juliane Wünsche (literature), Anke Schiemann (multimedia art), Ulrike Schmitz (photography), Robert Seidel (multimedia art), Ariane Stamatescu (performing arts), Anke von der Heide (media architecture), and The Swan Collective (multimedia art).[19]

The AURORA training program

The *AURORA School for ARtists* offers five one- or two-day training courses on AR and media production. They take place twice a year and are free of costs.[20] The courses build on each other and can be combined depending on previous knowledge and on how intensely the participants want to immerse themselves into AR. In cooperation with other projects, the AURORA team also organizes one-day workshops for special professional groups such as designers or performing artists. After attending at least two courses on the development of AR applications with Unity and Vuforia (with/without coding) and the concluding production lab course, the artists can apply for a workplace in the AURORA production laboratory. Here, they work with their personal tutors to implement their own AR application within three to six months. To save license costs, results can also be published under the INKA research group's own AR app *INKA AR*.[21]

Due to the coronavirus, the last face-to-face-courses took place in March 2020. Since then the AURORA team has worked on its basic AR program *AURORA Digital*. It consists of fifteen video tutorials in German that can be found **on** the AURORA website and on *Youtube*.[22]

The development of artistic AR applications in the AURORA production laboratory

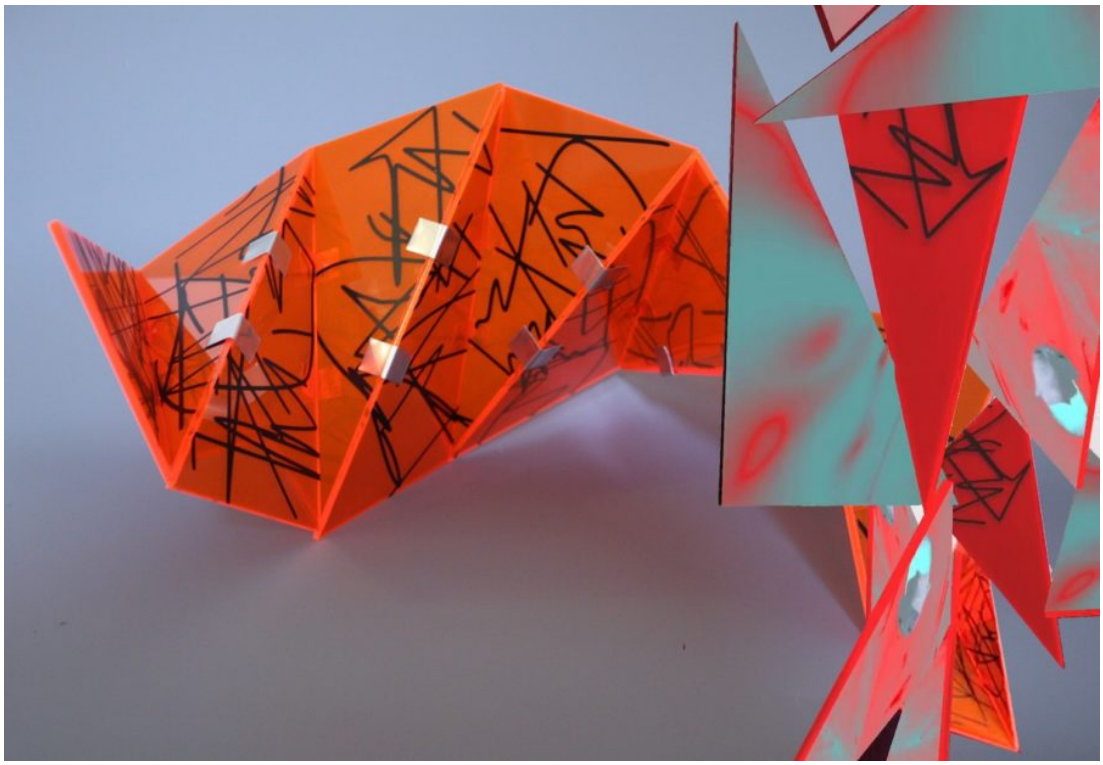

Figure 1: Dagmar Schürrer, Untitled (Von der Fläche zur Form), 2019, augmented sculpture, 40 x 25 x 20 cm. Photo: © the

artist.

In 2018/19, the video artist Dagmar Schürrer had a workplace in the AURORA production lab. Her initial idea for an AR artwork was an origami-like object made of acrylic glass and emanating a futuristic and yet enigmatic aesthetic. It looked almost as if somebody had thrown it through the window of a screen as a message of the digital world to be decrypted by its rhythmic hatching. And indeed, technically speaking the hatching, together with the object's form, should be recognized by the software *Vuforia*, triggering an additional layer of digital content: The sculpture serves as a multifaceted 3D screen showing parts of Schürrer's video *Seeking Patterns* (2019) as AR. The AR video fragments should then dissolve from the sculpture and expand into the three-dimensional space. With this concept, the video artist took up the idea of Expanded Cinema, which from the 1960s extended film material into flowing pictorial worlds in order to make it tangible in a new, sensual-aesthetic way (see Beckmann 2015). At the same time, Schürrer asked: "How far can this intention be realized with the new technical possibilities of object recognition and extension by means of AR?"[23]

The approach was convincing – but due to the state of the art at that time, the technical realization was anything but perfect: Although many tests were done to find the best solution, *Vuforia* wasn't able to lay the different videos exactly on the multi-angled planes of the sculpture. The technology had promised more than it could deliver. Only one year later, the new platform ARFoundation would have made the synchronization much easier, because it shows a reference of both the object and the projector in the Unity editor.

As such, Schürrer's AR concept was ahead of its time. In the end, the artist chose a new approach to spatially extend her video work: In *Virtualized AR* (2020), the AR layer is triggered by film stills of the video shown on a diagonal single screen on a self-built table, the new object. Like in a reverse mirror, the AR layer above the object shows motifs of the video *Virtualized* in form of moving 3D models expanding into the room (see Schürrer/Stark/Barsht 2019).

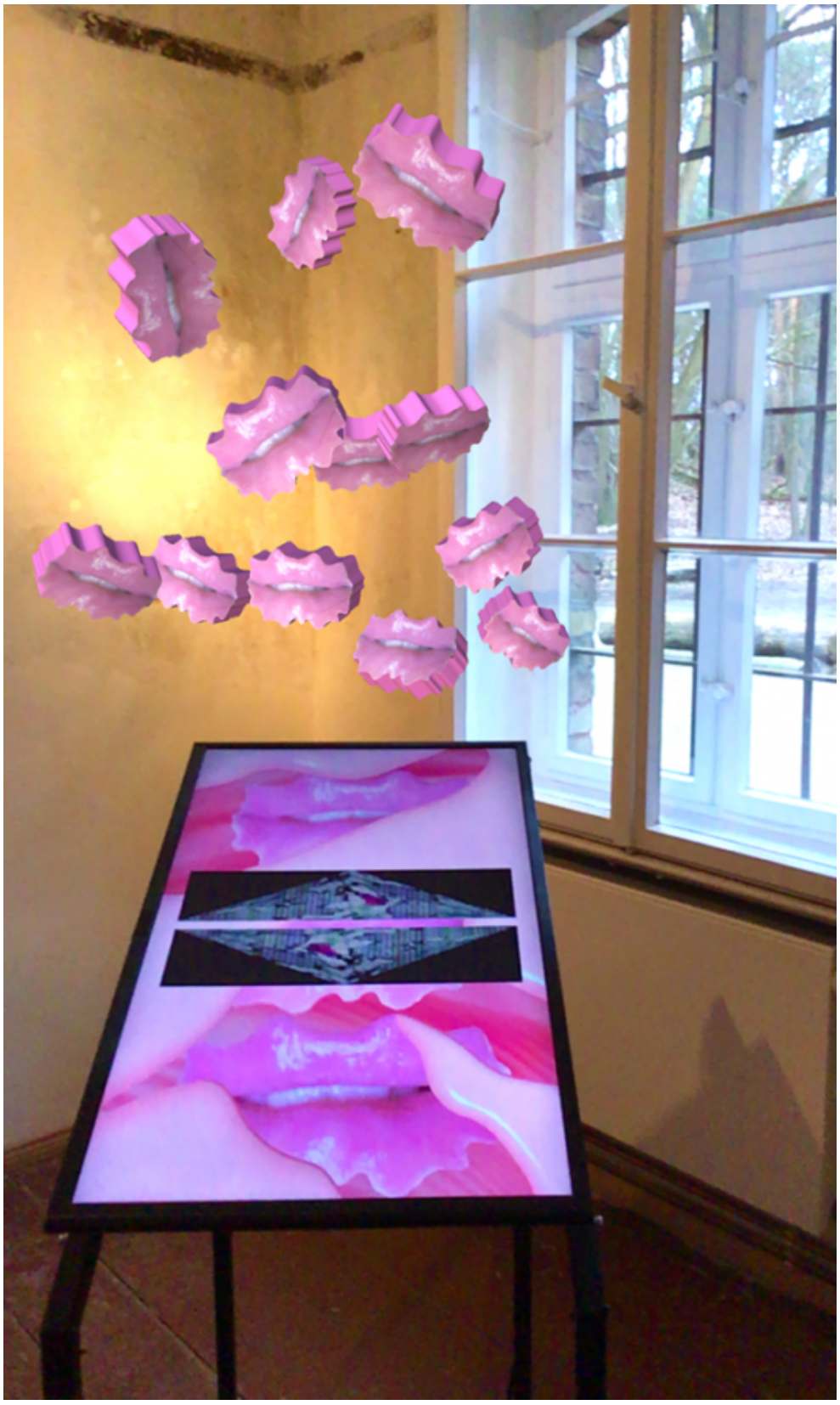

Figure 2: Dagmar Schürrer, Virtualized, 2020, AR video installation, two monitors, 10:55 min. Photo: © the artist.

As *Virtualized AR* has shown, the development of artistic AR applications is always a productive interplay – and sometimes struggle – between technical realization and creative process. Regarding AR as an artistic medium such as video, it has its own qualities and limits – and it will always influence the artistic result. The extent of this influence also depends on ongoing technical innovations and the artist-developer's skills with the technology. As mentioned before, there are not many courses on XR technologies at art academies yet. In the field of workshops for arts and culture professionals, the *AURORA School for ARtists* closed a gap. In this context, one has to consider that most of the AURORA participants have not yet worked with AR technology.

During a study with twelve AURORA artists (including two duos) in 2020, almost all of them stated that their concepts and ideas changed the more they deepened their knowledge about the technology in cooperation with their tutors.[24] On the one hand, this could mean a restriction – in the best case the artists could adapt their concepts to the technical limitations in a creative and productive way such as Schürrer, but also Theresa Reiwer: Her AR work *TOVIAS* is part of a narrative space – an analog room specially built by the artist and presented in 2019 (Reiwer et al. 2019).[25] The narrative of the immersive installation is advertised as a Smart Home prototype of the SLOW ROOMS series. The theatre guest is invited to test this Smart Home and its „certified relaxation tools" (brochure) in absolute isolation. Its latest feature is *TOVIAS*: The „Tool for Virtual Associate", an add-on that ensures that you never feel alone in a SLOW ROOM – unless you want it to, then you just switch it off – an installation that is more topical than ever before during the coronavirus pandemic and that empirically explores whether the basic human need for society is really so easy to satisfy.

Originally, *TOVIAS* was planned to take normal steps. But due to the complexity of the animation system, the virtual roommate moves short distances by taking many fast and tiny steps: He scurries. How could this problem be solved? The artist kept this original glitch as part of the concept.

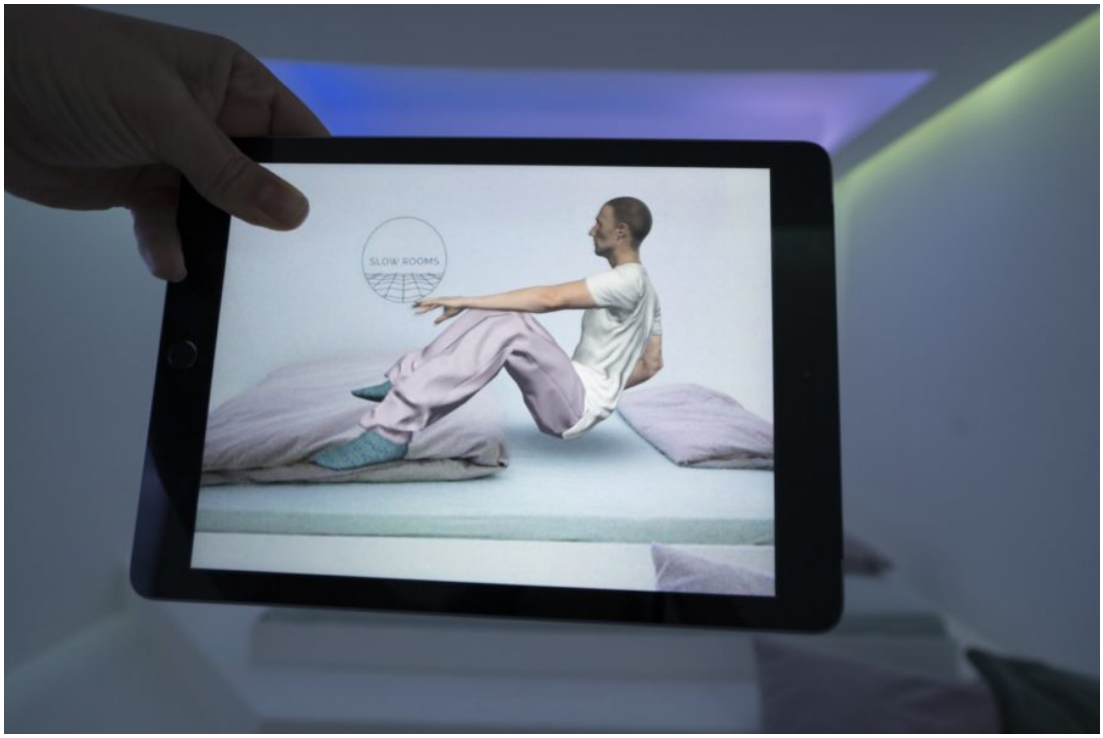

Figure 3: Theresa Reiwer, TOVIAS, part of AR room installation, 2018/19. Photo: © the artist.

On the other hand, the deepened technological knowledge led to an extension of the possibilities that the artists had not thought

about before and that inspired them to enrich their concept. This was described most vividly by author Juliane Wünsche: Asked to what percentage she was able to implement her original concept, she answered “120 percent”! Together with her AURORA tutor Leonid Barsht, she developed *Zittau 1999.* This AR application augments her novel *Nationalbefreite Zone* with additional historical, political and economic information. Especially in the field of *interaction* with the digital objects in the AR layer, a lot of new ideas arose during the interdisciplinary development process, e.g. a wipe function – a photography can be wiped away and a new image appears underneath – or the usage of a computer-generated 3D model of a projector that shows a slide show of the history of Zittau.[26]

These kinds of playful interactions are perfect for engaging and delighting the recipients – they are one of the main advantages of AR in art and art education, as can also be seen in the faces of the viewers of another interactive work produced in the AURORA production lab: Bianca Kennedy’s augmented drawing of a bathing scene, *Swimming with the Lovers* (2018/19), where you can evoke and then remove almost all AR components – analogue 2D drawings that are spatially arranged – by touching the screen. Each tap also leads to a surreal metamorphosis of the protagonist.[27] Wünsche’s and Kennedy’s applications can both be found in *INKA AR*.

Figure 4: Artists and AURORA team members interact with Bianca Kennedy’s AR drawing *Swimming with the Lovers* (2018/19) during a Retune Studio Visit at HTW Berlin. Photo: © Nushin I. Yazdani | *Retune.*

After their time in the laboratory, the twelve participants were interviewed and asked how far they got in implementing their original concepts: on average, this was 90%.[28] Technical restrictions and a lack of time were the main reasons when 100% was not achieved. The high percentage of 90% is due to the exclusive one-to-one-support, but also to creativity of the artists and the project’s five computer scientists (two of them students) who supported them as their AR tutors.

In the AURORA production laboratory, technical realization and creative process went hand in hand. Their interplay in the artistic practice has already been exemplified. But what about the computer scientists’ part? Usually, their creativity is focused on technical problem solving which again influences the artistic concept (as shown by the examples above). Similar to the artists, the AR

specialists' creativity also consists of selecting the appropriate material, but in terms of finding the most sensible approach/interfaces, components and plug-ins. Furthermore, computer scientists help to transfer the artistic to coding concepts in terms of building the program and structuring a flexible yet easy-to-use API. Last but not least, "beauty is in the eye of the beholder" (Hungerford 1878: 100). Computer science has its own aesthetic,[29] which is manifested in the choice of the best programming formulation being both elegant and readable: a 'beautiful code' is smart and structured clearly, it follows the coding conventions, is commented and comprehensible for other programmers, maintainable and expandable.[30] This beauty is invisible for the users – and at first glance not too important for the artists –, but it is important to computer scientists and crucial for the performance of an application. And who would want to have an artistic AR application that doesn't work well? The more complex an artistic AR concept is in terms of (inter-)actions, the higher the likelihood that at least a little programming is necessary. After a two-day programming course as part of the AURORA training, nobody expected that the artists in the AURORA production lab would do this completely independently. But the more previous knowledge they had and the more ambitiously they worked with the technology, the more progress they made. One third of the twelve interviewed artists said that they would continue to use the Unity editor including some programming.

Conclusion: Reflections on Artistic Training in Augmented Reality

The enormous interest of artists and other cultural professionals in the EU-funded AURORA project at the HTW Berlin clearly shows an urgent need for continuous Augmented Reality (AR) course offerings being tailored to their needs. In the area of training for freelancers in the independent art and culture scene in Berlin, the project could close an important gap. AR is the perfect breeding ground for a creative process of both artists and computer scientists, a permanent interplay of thinking and rethinking both artistic and coding concepts as well as technical feasibility.

The last three years of AURORA have shown that artists appreciate modular courses that they can combine individually. In addition to the current workshops, lectures on AR storytelling and ethical aspects based on philosophical studies would definitely make sense. This is also our recommendation for future course and study programs on AR and also VR art. These should best be implemented at media art academies and universities of applied sciences, where they can be combined with existing courses about digital media production and development with game engines such as Unity.

For art students with a strong focus on analog materials and body work, free courses like the AURORA workshops would be a reasonable complement to their regular studies. Visiting professors and guest lecturers are also a good idea. However, the analog artists' main focus should not be on technical development, but on a theoretical and philosophical framework, on examples and experiments with the technology. Finally, analog artists should become familiar with interdisciplinary workflows and networking, bearing in mind that they will at some point need interdisciplinary teams for discovering the expanding world of artistic expression in the Extended Realities.

Acknowledgements

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Annotations

[1] E.g. *Virtuelles Konzerthaus* by HTW Berlin project APOLLO in cooperation with the Konzerthaus Berlin, Germany, since 2015; *ArtLens-App*, Cleveland Museum for Art, Ohio, USA, since 2016; exh. *ORLAN Videorlan – Technobody*, Museo Macro Rome, Italy, 2017; exh. *Mixed Realities*, Kunstmuseum Stuttgart, Germany, 2018; the art education project *Hyperlink* on the exh. of Joanna Piotrowska, Kunsthalle Basel, Switzerland, 2020 etc.

[2] For terms and concepts such as Mixed and Hyper Reality see e.g. the *AURORA Digital* video tutorial. Online: https://aurora.htw-berlin.de/aurora-digital/ [04.01.2021]. For Hyper Reality see also the artistic video by the film maker Keiichi Matsuda (Matsuda 2016).

[3] DAM Projects. Online: https://damprojects.org/ [30.12.2020]

[4] Radiance. The international research platform for VR experiences in visual arts. Online: https://www.radiancevr.co [26.02.2020]

[5] Artivive. Online: https://artivive.com/ [29.02.2020]

[6] Adobe Aero. Online: https://www.adobe.com/de/products/aero.html [30.11.2020]

[7] VRHAM! Virtual Realites & Arts Festival. Online: https://www.vrham.de/ [29.02.2020]; Virtual Worlds Festival. Online: https://virtualworlds-festival.com/ [29.02.2020]

[8] Mixed Realities. Virtuelle und Reale Welten in der Kunst. Exh. 05.05.–26.08.2018. Online: https://kunstmuseum-stuttgart.de/index.php?site=Ausstellungen;Archiv&id=113 [04.01.2021]

[9] E.g. Bjarne Melgaard. Online: https://acuteart.com/bjarne-melgaard-at-julia-stoschek-collection-opening/ [24.02.2020]

[10] unreal.theatre. Online: https://unreal.theater [30.11.2020]

[11] IN VR WE TRUST. Online: https://www.nextmuseum.io/events/daniel-hengst-clemens-schoell-ueber-in-vr-we-trust/ [30.11.2020]

[12] Augmented Reality Biennale 2021 in Düsseldorf (News). Online: https://www.filmstiftung.de/news/augmented-reality-biennale-2021-in-duesseldorf/ [30.11.2020]

[13] AURORA developer André Selmanagić, 04.12.2020, interviewed by Maja Stark.

[14] Introduction into Augmented Reality (undergraduate course at the School for Visual Arts NY). Online: https://bfafinearts.sva.edu/course/introduction-augmented-reality/ [20.02.2020]; advanced Augmented Reality Apps (online course). Online: https://online.colum.edu/course/advanced-augmented-reality-apps/ [29.02.2020]; Augmented Reality (course by Kristin Lucas). Online: https://ima-mfa.hunter.cuny.edu/?ima-course=augmented-reality [29.02.2020]

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[19] For more information about the artists, their AR artworks and applications see https://aurora.htw-berlin.de/en/alumni-2/ [04.01.2021]; Busch/Kassung/Sieck 2019 and 2020.

[20] For the detailed program see https://aurora.htw-berlin.de [04.01.2021]

[21] The application can be downloaded for free in the Google Play and Apple App Store.

[22] See aurora.htw-berlin.de/aurora-digital and youtube.com/playlist?list=PLpOdBh7WW3Kaic_-LQSXGiLnvN-wl2Q3e [22.12.2020]

[23] Artist Dagmar Schürrer, 04.12.2020, interviewed by Maja Stark.

[24] 10 questions on the AURORA production laboratory (HTW study with twelve AURORA artists, not published).

[25] For Reiwer's AR roommate see https://aurora.htw-berlin.de/portfolio/theresa-reiwer-en [20.02.2020]

[26] For Wünsche's AR novel see https://aurora.htw-berlin.de/portfolio/juliane-wuensche-en [06.01.2021]

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[28] The values are between 45% (1x) and 120% (1x), most are between 85% and 100%.

[29] Thanks to the artist Dani Ploeger for the exchange on this aspect.

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Figures

1. Dagmar Schürrer, Untitled (Von der Fläche zur Form), 2019, augmented sculpture, 40 x 25 x 20 cm. Photo: © the artist.
2. Dagmar Schürrer, Virtualized, 2020, AR video installation, two monitors, 10:55 min. Photo: © the artist.
3. Theresa Reiwer, TOVIAS, part of AR room installation, 2018/19. Photo: © the artist.
4. Artists and AURORA team members interact with Bianca Kennedy's AR drawing *Swimming with the Lovers* (2018/19) during a Retune Studio Visit at HTW Berlin. Photo: © Nushin I. Yazdani | Retune.