



The Garage Journal:
Studies in Art,
Museums & Culture

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This item has been published in Issue 03 'The Museum as a Research Hub,'
edited by Vlad Strukov.

To cite this item: Nolasco-Rozsas L; Hofmann Y (2021) The Museum as a
Cognitive System of Human and Non-Human Actors. *The Garage Journal:
Studies in Art, Museums & Culture*, 03: 1–15. DOI: 10.35074/GJ.2021.8792.003

To link to this item: <https://doi.org/10.35074/GJ.2021.8792.003>

Published: 24 September 2021

ISSN-2633-4534
thegaragejournal.org

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The Museum as a Cognitive System of Human and Non-Human Actors

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The essay introduces a new line of research at the ZKM | Center for Art and Media Karlsruhe that examines the role and experiments with museum applications of information technology, specifically artificial intelligence (AI) and extended reality technologies (e.g., augmented, mixed, and virtual realities). Currently, two projects at the ZKM have taken up the initiative to start practice-

based research: *Beyond Matter and intelligent.museum*. These projects are discussed in this essay with the aim of demonstrating that the museum is being successively transformed into a cognitive system of human and non-human actors. Drawing on the institutional experience of the ZKM, we present a new approach towards the notion of the museum: one that takes computation into consideration.

Keywords: artificial intelligence, museum as a cognitive system, museum collaboration, practice-based research, virtual as a condition

Attempts to give a brief definition of the museum as a phenomenon seem to be futile today, especially if we look at ICOM's struggle with answering the question of what the museum of the twenty-first century actually is. The debate had already been going on for years when in 2019 the ZKM aspired to crowdsource a definition, which resulted in a collective Dadaist manifesto that adds to the plurality of alternatives (ZKM Magazine 2019).



Figure 1. A photo of the *Open Codes* exhibition opening (photo copyright: Felix Grünschloß, ZKM | Center for Art and Media Karlsruhe)

The ZKM did not only engage in a debate about this but organized a whole series of exhibitions under the title *Open Codes* (2017–2021)¹ that attempted to define at least partially the role of museums in a society increasingly driven by computer codes. *Open Codes* reflected on the world we live in today: a world that is created and controlled by codes. Since this series became the basis for our current investigations, its brief introduction is vital for understanding the roots of our arguments:

'*Open Codes* brings computing and art together in various ways. It is a new form of assembly, combining practical knowledge of computer code and critical artistic approaches in a single venue. The project seeks to empower its participants to regain access to reality through instruments of thought and to reflect on the genealogy and current social impact of digital code, computer programming, and software' (Peter Weibel 2017: 10).²

Open Codes understood the museum as a platform of exchanging and creating knowledge aided by a curated selection of exhibited artworks and by stakeholders who brought various types of expertise into the exhibition space. The events organized to elaborate on the exhibition's concept, often referenced as the 'accompanying' or 'educational' program, in case of *Open Codes* merged with the exhibition, underlying the idea of the museum as an assembly.

By the end of the twentieth century, various tendencies in museums propelled a revision of museology, and the term 'new museology' (Vergo 1989) was coined:

'During the 1980s and 1990s, the New Museology spawned all manner of more critical inquiry into exhibitions, collections, practices, and ideologies, fuelled by post-Marxist and poststructural theories of representation and spectacle' (Mathur 2019).



Figure 2. A photo of the *Open Codes. The World as a Field of Data* opening exhibition, September 1, 2018—January 6, 2019 (photo copyright: Anne-Sophie Stolz, ZKM | Center for Art and Media Karlsruhe)

Via the new lines of researches at the ZKM we argue that decades after the emergence of New Museology the substitution of the adjective 'new' shall be considered as we are sliding deeper into the 21st century, and as theoretical currents such as the actor-network theory (ANT)³ increasingly impact the discourse. Some of these concepts allow us to think of museums as cognitive systems that are not bounded to one single physical location and where human and non-human actors, specifically machinic agents, can be taken into consideration.

The application of ANT in the curatorial context has been elaborated on by Wiebke Gronemeyer (2018: 154–156). She suggests using the term 'material turn,' which she understands as an awareness of certain processual transformations that curatorial practices might cause, with an emphasis on the actor-network relation, resonating with ANT and the neologism of 'intra-actions' by Karen Barad (2007).

The impact of new materialist, posthumanist critical theories is taken into consideration in the material turn in curating, and thus in the museum, where curating can take place. Although ANT takes non-human actors into consideration, Gronemeyer (2018) does not emphasize the importance of computational actors in her theory. We argue that computational actors, or algorithmic agents, have a crucial impact on our cognition and thus cannot be left out from the 'material turn' happening in curating in various contexts, among others in the museum. Adding a new actor influences the equilibrium of the complete system, and implies the necessity of new terms, based on the vocabulary that has been evolving around computation.

We argue that until now computational agents were not taken into consideration (and if they were, then only marginally) while elaborating on the definition of the museum, which is a major deficit, since computation plays an inevitably increasing role in curation, mediation of art on view in a museum context, as well as in archiving and collection care.⁴ Therefore, we suggest calling the current tendency, characterized by the interdependency of physical and digital spaces of the museum, 'virtual condition.' Furthermore, we suggest to approach the museum as a cognitive system, a term that draws from currents of computer sciences and information technology and clearly stems from the vocabulary of cybernetics.

Cybernetics is a scientific movement that, for decades, has profoundly impacted thinking and creation in science, engineering, and the arts. It is a genuinely twentieth century phenomenon, rooted mainly in distinct forms of systems theory, which developed independently in different geographical locations. A crucial aspect in cybernetics is that it pointed out the intertwined nature of the biological and technological, which is a prerequisite for understanding the metaphor, coined in the 1950s, of 'artificial intelligence.' Cybernetics is nominally scarcely present in current discourses, but as Yuk Hui (2019) pointed out in *Recursivity and Contingency*, it has a crucial impact on our understanding of the term *technology*, and as a direct consequence, of the arts (and their relation to the term *techné*).

Cybernetics will also influence the notion of the museum, even if it adds a new element to a not yet clearly defined system.

Currently two international, collaborative, practice-based research projects, *Beyond Matter*⁵ (2019–2023) and *intelligent.museum*⁶ (since 2020), attempt to react to the current turn caused by the advance of computation in the museum, both from different vantage points. *Beyond Matter* addresses the already mentioned 'virtual condition' with a specific emphasis on its spatial aspects in art production, curating, and mediation via numerous activities and formats as case studies, including the digital revival of selected past landmark exhibitions.⁷ This common undertaking seeks to engage with a contemporary shift—largely attributable to the rapid development and ubiquitous presence and use of computation and information technology—in the production and mediation of visual art within institutional frameworks that may be summarized as 'the virtual condition.' If the postmodern condition was a 'crisis of narratives' (Lyotard 1992 [1979]: xxiii), the virtual condition reflects a crisis of dichotomies. Its analysis suggests that dichotomies are losing their validity: presence and absence, physical and computer-generated, real and simulated. The artificially generated increasingly dominates our reality, intertwines the physical with the virtual, and skews the linearity of time, which has a significant impact on the notion of the museum, and on the understanding of how museums work if information technology keeps developing at the current pace.

'Computer-generated simulations, virtual realities, networked digital platforms—from cyberspace to metaverse—are no longer fictitious locations found in science-fiction literature. Their significance and role are almost on a par with real spaces. Information technology has given rise to immaterial spheres that have become legitimate, parallel dimensions of our perception, experience, knowledge, communication and ourselves, where the real and the virtual are no longer antithetical opposites. For this reason, we must re-examine our three-dimensional conception of space.'

These words introduce the exhibition entitled *Spatial Affairs* (2021),⁸ realized in the framework of *Beyond Matter* at the Ludwig Museum Budapest in collaboration with and under the curatorial lead of the ZKM, as groundwork for the research on the virtual condition. The understanding of the notion of space that surrounds us is definitely a prerequisite for engaging with the artificial or generated spaces to be co-created and calculated by human and machine.

Naturally, this has extensive implications for the spatial aspects of curating and mediating visual arts, as well as their reception. Under such circumstances, the museum transmogrifies into a hybrid entity integrating a geographical location with various digital platforms. Instead of one single building, an affluence of exhibition spaces shall be taken into consideration while imagining a museum that becomes an extended but also porous system of multiple dimensions. Thus, the museum can be better understood as a system that is triggered by cognitive processes than a space bounded to a specific location.

This thought triggered the substantive focus of the *Hybrid Museum Experience Symposium (HyMEx)* (2021) that brought together leading researchers and scholars in digital and experimental museology, collection care, curatorial practice, as well as researchers from a broad spectrum of other disciplines to exchange views on challenging situations and latest innovations in the field of hybrid museum experiences. With *HyMEx* the organizers attempted to bring together pluridisciplinary perspectives that remain relevant and constitute a credible source of reference towards the artist, the artwork, the exhibition, the visitor, and the museum expert, via seeking interpretations of the hybrid museum experience within the contemporary art scene in the light of spatial and societal aspects.⁹ Beside the two mentioned outputs of practice-based research, *Beyond Matter* continuously implements projects that elaborate on the contemporary realities of museums, art mediation, and curation in an era when various factors, one of which is definitely computation and its all-encompassing impact, hinder museum professionals to define what a museum is.

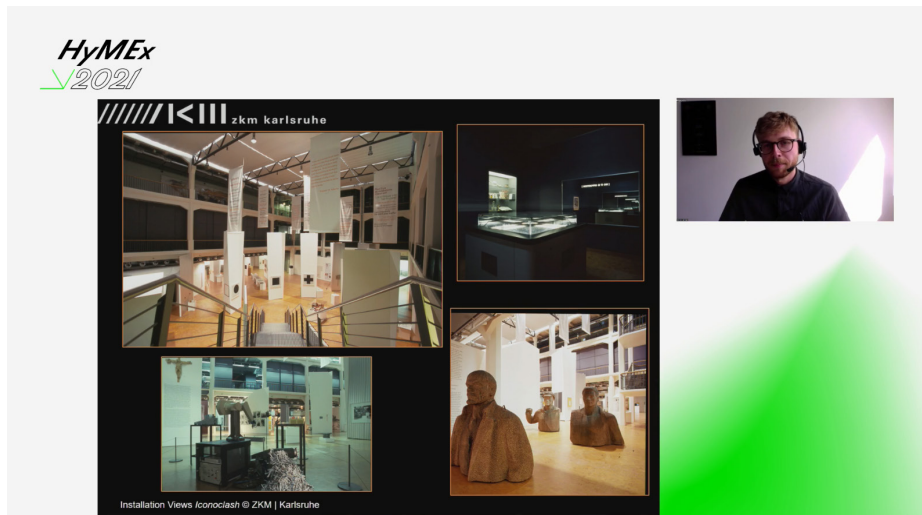


Figure 3. A screenshot of the online presentation of Felix Koberstein at the Hybrid Museum Experience Symposium on May 7, 2021

The arrival of the computer in art production happened already decades ago, but its impact is currently turning the infrastructure of the arts upside down. It is changing the role of museums within such a technology-driven ecosystem of art, as well as museums themselves. The walls of the museum dissolve as various digital spaces (from websites to digital exhibitions, social media channels, and online events) are added to the physical museum space, all of which are part of cognitive systems defined by various actors, rather than locations or objects. As outlined, central fields of activity of international museums are increasingly shifting to the digital realm. Physical museums, however, will not become obsolete in the future, nor will they ever be fully integrated into virtual museums. On the contrary, in the digital age, museums offer the potential to gain an insight into rapidly

accelerating developments in art, science, and technology, for instance, for less technology-savvy visitors and to reduce the physical–digital divide (Ball, Francis et al. 2019: 1167–1184). Hence, in the long term, meaningful connections between emerging virtual spaces with physical exhibition spaces will require the creation of well-designed interfaces that act like a permeable membrane between the physical and the digital to design the visitor’s user experience as intuitive and seamless as possible.

Since 2017, the artistic research and development platform at ZKM—the Hertz-Lab—investigates these new shifts in digital paradigms, with a special focus on interactive, haptic, and multimodal principles. Another focus of the Hertz-Lab is currently on the latest developments in AI technology and discourse. Significant progress has been made in AI in recent years, particularly in the area of artificial neural networks. In the late 1980s, when the ZKM was founded, artificial neural networks were still more of a theoretical research topic that could anticipate future developments. Their application was still underdeveloped and impractical for several reasons (Smolensky 1987: 95–109). Over the past two decades, however, progress in artificial neural network research has accelerated so rapidly, that today computers can learn from data and perform rudimentary cognitive functions previously reserved for humans. Artificial neural networks can recognize and automatically classify patterns from large amounts of data, make predictions, generate new patterns, or reconfigure themselves based on these patterns. The emerging AI technologies are disruptive and radically change various areas of daily life such as transportation, healthcare, education, public security or work (Stone et al. 2016). Though, in many cases, the underlying AI systems appear to be an opaque black box, making it difficult to engage with this technology on a broad societal scale.

The *intelligent.museum* project, which has been taking place at the ZKM in cooperation with the Deutsches Museum since the beginning of 2020, aims to inspire and empower museum visitors to critically engage with AI topics. It follows a human-centered approach to AI that is guided by humanistic values such as ethics. The human-centered AI approach, introduced a few years ago, places human society at the center of AI and consequently does not focus on merely technical factors (Li and Etchemendy 2018). The aim of the project is to question current developments, to explore their potential and expanded fields of application of AI in the museum, and to look at them from different perspectives. For this reason, the *intelligent.museum* project brings content and topics to the public through practice-based research and the development of prototypes, hands-on demonstrations, and tangible presentations.

For this purpose, international artists who bring AI technologies into their artistic practice are invited to develop and realize an artistic work within the framework of an artistic residency at the ZKM and Deutsches Museum. From speculative fictions to hyperreal images to AI-composed soundtracks, artificial neural networks can be used multifariously, for instance, in interactive installations, generative videos, data visualizations or

sonifications. The expressive possibilities of digital art stimulate a level of critical reflection. The *intelligent.museum* residencies in summer 2021 at the ZKM and Deutsches Museum highlight the extent to which artists are already meaningfully integrating AI techniques into their artistic practices, but more importantly, how they evaluate the social impact of technology and raise questions.

Media artist and composer Alexander Schubert wants to encourage critical reflection on social media and data sovereignty with his work *CRAWLERS* (2020). The hybrid artwork has already been realized as part of the *intelligent.museum* project. The artist developed an anonymous collective of social bots operating on social media that collect users' data. Using different AI methods (e.g., convolutional neural networks and generative pretrained transformers), images and postings of the users are transformed and fed into an alternative social network in a modified but similar form. On site in the exhibition space, the artwork manifests as a multi-screen installation that visualizes both social media profiles of the parallel social network and the machine learning processes. Alexander Schubert raises awareness of the permanent and ubiquitous practices of automated data theft on the net and reflects on the impact of technical actors on our digital identities.



Figure 4. A photo of Alexander Schubert's work (*CRAWLERS*, 2021; photo copyright: Elias Siebert / ZKM | Center for Art and Media Karlsruhe)

From early summer 2021, further residencies will be realized as part of the *intelligent.museum* project. French artist Gaëtan Robillard condenses his reflections on social polarization caused by emerging fake news and post-truthism into an aesthetically coherent work of art entitled *Patterns of Heat* (2021): with the help of AI techniques, Robillard measures the presence of fake news on the Internet that refer to the climate crisis and are spread over the digital ether. Robillard will translate this into a data-driven artistic floor installation that uses heat radiation to transport effects of the climate crisis into the exhibition space. For exhibition visitors, however, it is not global warming in relation to the overheating of the earth that will be felt, but rather the friction energy between post-facticity and

scientific consensus.

With *Proteus 3.0* (2021), artist duo Maria Smigielska and Pierre Cutellic, aka Compmonks, are developing an interactive behavioral video installation. The artists use computer vision technology and deep learning models to capture the viewers' posture, gaze direction, and facial expressions and have them influence a constantly changing digital emulation of ferrofluid.

Using computer vision technology in a totally different scenario, Giselle Beiguelman, Bruno Moreschi and Bernardo Fontes want to find out to what extent colonialist patterns and gestures are inherent to human images. The project *The Imperialist Gaze* (2021) aims to shed light on how convolutional neural networks can interpret digitized images and be instrumentalized for the analysis of large-scale image collections.

Katrin Hochschuh and Adam Donovan developed an *Empathy Swarm* (2019–) of robots that can perform spatial choreographies and interact with exhibition visitors. In the exhibition space, visitors will be able to train the swarm using reinforcement learning and confirm or reject it based on their own reactions and gestures.



Figure 5. A photo of *Empathy Swarm*, an interactive robotic swarm, human-machine biofeedback system, by Katrin Hochschuh and Adam Donovan (WRO 2019 Biennale / HUMAN ASPECT, Wrocław, Poland; photo copyright: Wojciech Chrubasik)

All of the aforementioned artistic projects are experimental setups that apply data-driven applications of AI in different scenarios, and while they do not, of course, offer directly scalable solutions for the museum itself, they serve as case studies to the *intelligent.museum* project. From these case studies many new perspectives on the reciprocal relationship between museum visitors and the museum will emerge. One of the main goals of the *intelligent.museum* project is to open up the black box mentioned above in order to make AI technologies more accessible to both artists and the general

public. To ultimately enable all museum stakeholders to learn more about the vast topic of artificial intelligence, all source codes developed as part of the *intelligent.museum* project are continuously posted to an open-source code repository.¹⁰ They are publicly available for further use or discussion.

In order to significantly simplify working with AI and also empower people without AI knowledge, low-threshold digital tools are being developed at ZKM.¹¹

The *intelligent.museum* project is exploring the extent to which AI technology can be used to break down barriers in the exhibition space and make the museum experience more inclusive and accessible. The emerging cognitive capabilities of artificial neural networks can be investigated in diverse and multimodal interaction scenarios and, when implemented responsibly, computer vision, conversational user interfaces (dialog-oriented interfaces that emulate a conversation with a real person), or natural language processing/understanding for voice user interfaces open many new perspectives on the reciprocal relationship between museum visitors and the museum. Among the recent developments of the project team are, for instance, intelligent digital text labels that can recognize the spoken national language of exhibition visitors while automatically adapting to reduce language barriers. For this, museum visitors converse with an artwork or exhibit that is able to recognize their spoken national languages and then translates a digital text label with meta-information into the appropriate language.

In addition, rapid prototypes of museum operational applications are currently being developed and tested in the exhibition space to see how automation and machine decision-making processes can support the operation of exhibitions. Ongoing experiments involve both semi-autonomous machine decision-making processes (e.g., suggestion of an admission stop by a machine agent to a human operator in the museum entrance area when the visitor capacity limit is reached, which occurs as a result of an automated visitor count) and fully autonomous machine decision-making processes, such as the automated regulation of technical functions of the museum (e.g., the volume of sound installations in exhibitions, which can be automatically regulated depending on the number of visitors).

In the *intelligent.museum* project, cognitive technical systems serve as an orientation model for designing a speculative scenario for museums integrating cognitive computing with sensors and actuators in the exhibition space. Cognitive technical systems are technical systems 'equipped with artificial sensors and actuators integrated and embedded into physical systems, and act in a physical world' with cognitive capabilities such as perception, representation and reasoning, learning, communication and interaction.¹² The research and development area of cognitive systems engineering emerged about forty years ago from the realization that the then existing approaches to human-machine systems considered only physical or mechanical functions, but well-functioning human-machine systems require a different kind of knowledge that describes the cognitive or mental functions of a human-machine system (Hollnagel and Woods 1983). Since then, of

course, many quantum leaps in research have taken place, and in particular the advancements in AI and the emergence of cognitive computing are now leading to integrated technical systems that can observe and classify the environment, perform actions, make decisions, and solve problems. Such systems are becoming active learning systems that can acquire knowledge and in turn make it available to humans. For the *intelligent.museum* project, the goal is to create new communicative situations between visitors, art, curators, and the museum. Through multimodal interfaces between the digital world and the environment, the museum could be able to perceive and understand things in the long term, determine things from people's reactions, and adapt to its environment and respond to visitors by combining sensor data from different sources with data-driven applications. This would actively support the learning process as it would help both visitors and the museum to 'exchange, learn with and from each other, while at the same time transforming the original museum space into a shared space of knowledge and experience' (ZKM Editors 2020).

Albeit the outlined research draws from various disciplines, such as contemporary museology, techno-philosophy, and technology, it actually takes place in functioning museums and manifests itself in various artistic and curatorial projects, thus it shall be inevitably practice-based. Any interim result of such a practice-based methodology that is enabled by collaboration with artists can and shall be immediately exposed to and thus validated by museum visitors, who close the feedback loop in the cognitive system.

In both projects, *Beyond Matter* and *intelligent.museum*, practice-based research is understood as a process within the museum context that includes the development and creation of hands-on experiences (i.e., interactive exhibits with novel applications), their evaluation with the inclusion of the audiences, and creating open-source best practices for museum professionals, who are increasingly required to apply digital tools.

To conclude, the museum of the future shall be approached as a cognitive space, which is an affluence of actual, virtual, and cognitive networked spaces, in which the visitor and the curator are not the only actors. As machinic intelligence rises, non-human algorithmic agents play an increasingly important role in the hybrid ecosystem of a museum. In this constantly shifting network of relationships between human and non-human agents, our role as museum professionals is 'post-custodian.'¹³ Indeed, under such hybrid circumstances, more experimental approaches and artistic mindsets shall be given space, especially in times of social distancing, implied by the COVID-19 pandemic, that inevitably accelerated digital mediation in the museum context.

It seems that no singular museum definition is possible, or it shall be so pluralistic that it might fray the boundaries of a definition. Giving a finite, compact, and approximately universal portrait of all museums is also challenged by the fluidity of its social embeddedness and the exponential development of information technologies. Thus, constant re-examination is necessary, which is why research plays an equally important role in museums

as before, albeit with a different focus. While earlier the collection, its classification, contextualization, expansion, and care took up significant part of research resources at museums, lately, in addition to this still fundamental task, a new line of research emerged. Instead of verification and facts proof, speculation and invention are the foci of this research work that has been started at the ZKM and engages specifically with the nature of future museums¹⁴ that is deeply intertwined with and dependent on information technology. This is the dependence that propels the necessity to describe the museum as a cognitive system.

1. The series, based on the concept of Peter Weibel, started at the ZKM in 2017, under the title *Open Codes. Living in Digital Worlds*, and was followed by a second iteration, *Open Codes. The World as a Field of Data* at the ZKM, while satellites were organized, for example, at the Azkuna Zentroa Bilbao (*Open Codes. We Are Data*, 2019–2020), the Chronus Art Center Shanghai (*Open Codes. Connected Bots*, 2019), or the Nam June Paik Art Center, near Seoul (*Open Codes. Networked Commons*, 2021).
2. From the *Open Codes. Connected Bots* exhibition concept published in the exhibition brochure (Shanghai: Chronus Art Center, 2019), p. 10.
3. Although the actor-network theory (ANT) is rooted in the twentieth century, developed at the Centre de Sociologie de l'Innovation (CSI) in the early 1980s, and was already applied by Bruno Latour in his curatorial practice from the 1990s, its broader impact on curatorial discourses can be traced later, as indicated by the publication of Wiebke Gronemeyer's *Curatorial Complex* in 2018. In this essay, we follow the Latourian definition of ANT (Latour 1996).
4. Curatorial research is increasingly drawing from online databases and other digital resources, archivists digitize metadata on the collections, and since museums increasingly collect born-digital assets, the actual artifact shall be stored digitally. Mediation and museum communication are equally impacted; online educational programs thrive, especially as a result of the recent lockdowns due to the COVID-19 pandemic. In exhibition venues information on artworks and interactive applications in relation to them are presented on computer screens.
5. <https://beyondmatter.eu>
6. Page of the *intelligent.museum* project: <https://zkm.de/en/project/the-intelligent-museum> (21.09.21).
7. The chosen exhibitions are *Les Immatériaux*, which took place at the Centre Pompidou Paris in 1985 and was curated by Jean-François Lyotard and Thierry Chaput, and *Iconoclash*, which opened in 2002 at the ZKM | Karlsruhe and was curated by a group of leading experts of their fields lead by Peter Weibel and Bruno Latour.

8. <https://www.ludwigmuseum.hu/en/exhibition/spatial-affairs>
9. Paragraph based on the concept of HyMEx Symposium. <http://hymex2021.ludwigmuseum.hu>.
10. <https://git.zkm.de/Hertz-Lab/Research/intelligent-museum>
11. In this context, the `ofxTensorFlow2` extension for the open-source toolkit `openFrameworks` was recently published in the ZKM's code repository. `ofxTensorFlow2` is a new interface between TensorFlow 2, a common toolkit for training machine learning models, and `openFrameworks`, where the trained models can be used. The add-on automates the connection between the two tools to a large extent and AIs trained in TensorFlow 2 can be easily loaded and executed in `openFrameworks` (despite the different programming languages of the two toolkits).
11. According to U.S. computer scientist Ronald J. Brachman, these 'four capabilities form the core cognitive part of a cognitive information processing system' are: 1) computational perception, 2) representation and reasoning, 3) learning, and 4) communication and interaction (Brachman 2002).
12. Joasia Krysa in her presentation on the HyMEx Symposium, entitled *The Next Museum Should be Curated by a Machine*, uses the phrase 'post-custodian' to describe a shift towards an understanding of the museum that is 'more experimental, less determined by architecture, operating across hybrid actual and virtual modes, both online and offline.' — based on the abstract of the author, URL: <https://hymex.online/virtual/#/?hash=9a7b-b2961e8b843aa6212126494bdf2c> (21.09.21).
13. The methodological considerations have been influenced by the Irit Rogoff's term, 'the research turn,' that denotes process of how research has moved from being a contextual activity that grounds production and exhibition of art, to a mode of inhabiting the art world in its own right. The latest terminology of Rogoff suggests an internalization of the research process (Rogoff 2018).

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17. ZKM Magazine (2019, April 25) What is your museum of the future? <https://zkm.de/en/magazine/2019/04/what-is-your-museum-of-the-future> (21.09.21).

Authors' bios

Livia Nolasco-Rózsás is a curator and researcher. She has curated exhibitions raising questions on the genealogy and social impact of planetary computation, electronic surveillance, and democracy, or synesthetic perception at institutions of contemporary and media art worldwide, including at the ZKM | Center for Art and Media Karlsruhe, Chronus Art Center (Shanghai), or Tallinna Kunstihoone. As of 2019 she has started a research in curatorial studies on the 'virtual condition' and its implications in the exhibition space at the Academy of Fine Arts Leipzig, and as acting head of the project BEYOND MATTER (2019-2023) at ZKM | Karlsruhe, which she initiated.

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ISSN-2633-4534
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