Workshop

"Writing the History of Computer Visualizations in the Sciences: production, uses, circulation (1940-1990)"

Organized by the ANR project DESIGNSHS

2-3 May 2024

Écoles des Hautes Études en Sciences Sociales
Salle A/BS1_28
54 boulevard Raspail
75006 Paris

Timetable

Thursday, 2 May

9h15-9h30: *Morning Coffee*

9h30-10h00: *Welcome by organizers* (Edgar Lejeune)

10h00-10h45: Nina Samuel (HU Berlin)
"Pixels and Pencils: On the Relationship between Abstract Reasoning and Visual Imagination in Complex Dynamics and Fractal Geometry (1960–1980)"

10h45-11h30: Alexandre Hocquet, Frédéric Wieber (Archives Poincaré, Université de Lorraine), Phillip H. Roth, Alin Olteanu (KHK Aachen)
"Juggling Molecules"

11h30-11h45: *Coffee Break*

11h45-12h30: Clément Bonvoisin (SPHERE, Université Paris-Cité)
"Computer visualizations for the U.S. Air Forces: Arnold Mengel and the uses of an analogue computer at RAND Corporation (1946–1954)"

12h30-14h30: *Lunch Break*

14h30-15h15: Arianna Borrelli (TU Berlin & Bielefeld University)
"Image, not logic: computer-aided data visualization in microphysics and the transformation of the notion of particle"

15h15-16h00: Grayson Bailey, Nathalie Bredella (Leibniz University & TU Munich)
“**Computational mapping techniques und knowledge cultures within Landscape, Design and Planning**”

16h00-16h45: Michael Friedman (Cohn Institute & KHK Aachen)
“Computer Visualizations of Mathematical Objects during the 20th Century”

16h45-17h00: *Coffee Break*

17h00-18h00: *Key Note Presentation* - Janina Wellmann (MPIWG, Berlin)
“Visualization, Computation and Mathematics. Images in the Age of Computer”

Friday, 3 May

9h00-9h30: *Morning Coffee*

9h30-10h15: Youssef Abdel Aziz (American University of Cairo & SPHERE, Université Paris-Cité)
“The Monte Carlo method and the development of computer graphics”

10h15-11h00: Emma Larcelet (EPFL)
“**The continuity of architectural drawing within early computer-aided experiments: from research to academic experimentation (1960—1990)**”

11h00-11h15: *Coffee Break*

11h15-12h00: Mario Schulze, Sarine Waltenspül (University of Lucerne)
“**Quantifying flow? About the history of Particle Image Velocimetry (PIV) and how to turn a flow film into a data film**”

12h-12h30: *Conclusion*

ABSTRACTS

Pixels and Pencils: On the Relationship between Abstract Reasoning and Visual Imagination in Complex Dynamics and Fractal Geometry 1960 – 1980

Dr. Nina Samuel

Research Group Object, Space, Agency (Humboldt University, Berlin)

The images of chaos and fractal geometry are probably the best-known mathematical symbols of the rise of computer visualization in the sciences. While these popular pictorial inventions of the mid-1980s and 1990s had a rather low epistemic potential and no direct relation to the operations of the thinking mind, the situation was quite different in the years before their popularization.

The lecture covers the period 1960-1980, when early attempts at computer visualization gave rise to new hypotheses in the field, and the development of techniques led to new experimental approaches. The circulation of images between different "styles of thinking" (Ludwik Fleck) was essential for the dissemination of theories across disciplines and had a direct influence on the development of scientific questions. Observation began to play an entirely new role, triggering controversial attempts to redefine the notion of mathematical proof. This can be illustrated by the story of the discovery of the Mandelbrot set, in which the question of pictorial evidence and different computer resolutions between research and industry played a central role and deeply affected the observed mathematical phenomena. But the talk will also look at earlier examples and analyze the first experiments with diagrams, tables, plotter images, thermographic prints, and ASCII graphics, which are not widely known in the context of this research field. Based on a large number of conversations, correspondence and visits to personal workplaces and archives, the lecture will touch not only on Benoît Mandelbrot's use of computer visualization, but also on that of other related scientists from the USA, France, Japan and Germany (Edward Lorenz, John Hubbard, Adrien Douady, Yoshisuke Ueda, Otto Rössler).

Crucially, the advent of computer-generated images required a critical approach to these new tools. It was imperative for mathematicians and scientists to maintain a distance from images in order to use their potential and understand their limitations. In this context, the interplay between computer visualizations and hand-drawn images emerged as a central epistemic practice. The pencil, far from being replaced by the computer, played a crucial role in the conceptual development of the field. Its importance grew with the proliferation of computer-generated images, serving as an indispensable tool for extracting coherent theoretical ideas from the vast array of visualized data. In many cases, the transition from a complex, experimentally generated image to a clear, conceptual understanding was facilitated by the simple act

of drawing a line. This practice underscores the continued relevance and necessity of traditional methods in the midst of technological advances, and highlights the complementary nature of different visualization techniques in the pursuit of scientific understanding.

Short biographical note

Art and science historian; curator. Academic positions include: Bard Graduate Center (NYC), eikones (Switzerland), Max Planck Institute for the History of Science (Berlin), Leuphana University (Lüneburg), Humboldt University (Berlin). Research Areas: History of science & image studies; visual epistemologies of mathematics; digital & technical images; microscopy; exhibition as research method.

Juggling Molecules

F. Wieber (1), P.H. Roth (2), A. Olteanu (2), A. Hocquet (1,2)

(1) Archives Poincaré, UMR 7117, Université de Lorraine

(2) c:o/re KHK, RWTH, Aachen

Our work focuses on the history of computational chemistry, a scientific field concerned with the modelling of chemical properties of molecules (and materials). Armchair scientists wearing stereoscopic glasses in front of their Silicon Graphics workstation is the archetypal "image d'Epinal" of the computational chemist of the 1980s. Because of its advent in times of entrepreneurship science incentives, because of its proximity to the pharmaceutical industry on the one hand and hardware manufacturers on the other, computational chemistry has been dealing with academic norms as well as business norms. The community of computational chemists also emerged in times of a plural and evolving hardware ecosystem, from the 1960s to the 1990s. In this context, the visualization of molecules on screen has been pivotal for the diffusion of computational chemistry models within chemistry, and towards the pharmaceutical industry.

We argue that the genealogy of modes of representation in chemistry, from Ursula Klein's "paper tools" to physical 3D models to visualization of molecules on the computer screen is incomplete without also accounting for the active role computational models play. Molecular mechanics is one of these computational models of molecular structures. It makes use of simple mathematical methods, but potentially requires many parameters to model concrete chemical structures. It evolved from a simplistic mathematical model of molecular structure in the 1950s to a computationally tractable model whose complexity lies in the handling of gigantic tables of parameters and data to feed this simplistic model in the 1970s. Hollywoodian ball and sticks on the computer screen then allowed for a performative representation of these models, in the 1990s. These dynamics, in turn, reflect the evolving plural hardware ecosystem throughout these decades.

Representations of molecules on screen align with a view of chemistry that developed during the 19th century, in which molecules are composed of atoms and bonds, whose lineage has been described in Klein's concept of "paper tools". They nevertheless offer a dynamical view of molecules, one that diverges from the underlying rigid view of 3D physical models. By drawing on the case of molecular modeling, we thus explore the performativity and materiality of "computational tools" that underlines the entanglement between models and media. Computational tools obviously refer to how the computer shapes scientific practices. Yet, unlike the overarching concept of "digital turn", computational tools are local, situated, and focus on users and uses. We argue that different media and modalities, through their affordances, shape modeling: the physical ball and stick model, the printer, the graphics terminal, the software interface all transform the object of study itself.

Short biographical notes

Frédéric Wieber is a Maître de Conférences in HPS at the Archives Poincaré in Nancy. https://poincare.univ-lorraine.fr/fr/membre-titulaire/frederic-wieber

Alin Olteanu is a Postdoctoral Researcher in Semiotics at the KHK Cultures of Research in Aachen. https://khk.rwth-aachen.de/dr-alin-olteanu/

Phillip H. Roth is a Postdoctoral Researcher in STS at the KHK Cultures of Research in Aachen. https://khk.rwth-aachen.de/phroth/

Alexandre Hocquet is a Professeur des Universités in HPS at the Archives Poincaré in Nancy. https://poincare.univ-lorraine.fr/fr/membre-titulaire/alexandre-hocquet

Computer visualizations for the U.S. Air Forces: Arnold Mengel and the uses of an analogue computer at RAND Corporation (1946–1954)

Clément Bonvoisin

SPHERE, Université Paris-Cité

After the Second World War came to a close, the US military sought to maintain the links they had established with scientists during the war. It did so through a variety of organizations which sponsored research in universities and the industry. Among these sponsored researches was the Cyclone project, which aimed at the development of an electronic analogue computer. Such a computer would allow for the simulation of the behavior of a system by looking at the behavior of an analogue electronic circuit. In

1946, the project resulted in the production of the *Reeves Electronic Analogue Computer* (REAC).

In this talk, I wish to discuss the use of the REAC for computer visualizations through the work carried out by an US electronic engineer, Arnold S. Mengel (1919–1986). In 1946, Mengel was hired by the RAND Corporation, a newly-created organization funded by the U.S. Air Forces. There, Mengel advocated for the purchase a REAC—which RAND eventually did in 1948. My focus will be on the uses Mengel made of the REAC to generate plots, in two series of works carried out from 1946 through 1954. The first one was concerned with finding the best paths for aircrafts and missiles to reach given aims. The second pertains to the study of tactical air war, a specific type of warfare under discussion in the United States over the 1950's.

Available sources on these researches allow us to address several historical questions on visualization practices in this context. How was the work necessary to produce the plots distributed among RAND Corporation's research staff? Within these research projects, what were the roles of such visualizations, and what did they allow researchers to do? What were the shortcomings of this approach that scientists and engineers at RAND encounter? To address these questions, I will discuss each series of works. I will begin by describing the mathematical work required to generate plots on the REAC, and the collectives gathered around Arnold Mengel to carry it out. I will then look at the plots themselves, to illustrate the problems experienced in producing them, the analyses and inferences they allowed researchers to make, and the questions they inspired. In doing so, I wish to illustrate the variety of uses computer-generated visualizations had for scientists and for the military in the early days of the Cold War.

Short biographical note

I am Clément Bonvoisin, a Ph.D. student in history of science at SPHERE and Université Paris Cité. My research is on mathematical optimization tools during the Cold War, with a focus on transnational circulations of knowledge, interactions between mathematicians, engineers and the military, and computers and computations in contemporary mathematics.

Image, not logic: computer-aided data visualization in microphysics and the transformation of the notion of particle

Arianna Borrelli

Techniscal University Berlin and Bielefeld University

In *Image and Logic* (1997) Peter Galison argued that, in the late 1950s, two different material cultures of microphysics collided: an older one where evidence of particles took the visual form of tracks in detectors, and a newer one prioritizing statistical evidence based on electronic counters connected to the detectors. The image of the so-called "golden event" proving the existence of a new kind of particle thus gave way to the logic of statistical analysis of large amounts of digital data. Enablers of this transition were electronic, digital computers which had recently found their way into the particle physics laboratory allowing to manage unprecedentedly large data sets. Against this by now classical narrative of the impact of computing tools on particle physics, I will argue that what Galison framed as a transition from image to logic was in fact a shift between two different modes of visualization: from analogue tracks to digitally generated diagrams presenting in visual form the statistically defined, but physically relevant properties of data sets.

While Galison acknowledged that the two traditions merged into electronically produced images, which he called "hybrid logic-images," he still argued for a break between a "mimetic" and a "logic" tradition of experimental evidence. Yet no image is "mimetic" in itself, and each culture of visualization is entangled with an own reality which the images mimic. In this new visual mode, the signature of a particle did not any more take the form of a path in real space, but instead looked like a peak or a bump in probability space. It was a shift both in the nature of evidence and in the notion of particle and, from the early 1960s onward, microphysical phenomena which had so far never been thought of as particles became particles for the simple reason that, when statistically visualized, they looked like particles. This transition should not be understood as a straightforward consequence of the introduction of computers in the laboratory, but rather as part of broader changes in the practices of microphysics. Indeed, it is only in that particular historical context that the introduction of a specific computational methods - Monte Carlo simulations - can be understood. Yet once the Monte Carlo method had entered particle physics, it in turn came to shape it in new ways, also thanks to the new visualization modes it made possible.

Short biographical note

Arianna Borrelli is a historian and philosopher of natural philosophy and modern science. Her present research project aims at historicizing the so-called Digital Turn in the natural sciences. She habilitated in history of science at the Technical University Berlin (2018) and is currently teaching as substitute professor at Bielefeld University.

Computational mapping techniques and knowledge cultures within Landscape, Design and Planning

Grayson Bailey and Nathalie Bredella

Leibniz University Hannover & TU Munich

Founded at the Harvard Graduate School of Design (GSD) in 1965 by Howard T. Fisher with the support of Dean Josep Lluis Sert and a grant from the Ford Foundation, the Laboratory for Computer Graphics and Spatial Analysis (LCGSA) was one of the first academic environments in which experiments in computer-assisted visualizations materialized in the context of architecture/landscape planning. The LCGSA created automatic mapping and visualization techniques to communicate measurable data in spatialized contexts, replacing traditional visualization and analysis methods, which laid the foundation for Geographic Information System (GIS) and its importance in contemporary spatial analysis.

The focus of the LCGSA was interdisciplinary, applying new computational methods to problems of Architecture, Landscape Engineering and Geography, and emphasized collaborative work – collaboration between the machine and the researcher, between students and instructor, and between various research centers. The LCGSA established research connections with geography departments in the US and UK, as well as with interdisciplinary discourse networks in Europe, such as those cultivated by Ekistics (the science of human settlements) founded by architect and urban planner Constantinos Doxiadis.

In a conversation last year with Carl Steinitz, original member of the LCGSA and Professor Emeritus of Landscape Architecture at the GSD, we discussed the initial projects of the LCGSA, the pedagogical atmosphere during the late 1960s, and the reception of their newly developed and applied techniques. It was clear that the process of convincing internal and external skepticism was largely in moving from instinctive evaluations of manually rendered images to evaluating design proposals based on the innate logic of the new computer-drawn maps. However, the inherent media politics of these emergent techniques were not of immediate importance; with an atmosphere focused on experimentation, the scientific and critical orientation of the LCGSA projects were much more in line with modern start-up culture (i.e. disruption, outcome outweighing the means, "proving that we can do it", etc.) than that of critical academic research.

In further investigating the works of LCGSA and related histories of computer research during the post-war period, our focuses are: (1) The effect of computer visualizations on observational and epistemological practices in architectural, landscape and urban planning, (2) the situated histories of establishing and managing discursive modes of communication and dissemination, (3) the networks of artifacts (hardware and software) and related media involved therein. Generally, our work hopes to further an understanding of the material and immaterial conditions of computer-based research in the post-war period among planning disciplines and to critically position such histories in terms of a critical media politics.

Short biographical notes

Grayson Bailey teaches at the Chair for Architectural Theory at Leibniz University Hannover. With Masters in Media-Architecture and Situated Technologies from Bauhaus-Universität Weimar and University at Buffalo, Grayson research focuses on overlaps of the architectural/political, influences of new media in architectural contexts, and cybernetic ideology in planning cultures.

Nathalie Bredella is Professor of Architectural Theory at Leibniz University Hannover and the Anna Boyksen Fellow at TU-Munich Institute for Advanced Study. She previously held fellowships at Bauhaus-Universität Weimar and the Leuphana University Lüneburg MECS Institute for Advanced Study with emphasis on multidisciplinary engagement in architecture and media studies.

Computer Visualizations of Mathematical Objects during the 20th Century

Michael Friedman

Cohn Institute, Tel Aviv University & KHK Aachen

When talking about mathematical models and the associated visualizations at the end of the 19th century, it is important to be clear which objects are being referred to. In 19th-century mathematics, 'model' clearly referred to material, three-dimensional objects, that is, to objects that one could pick up in one's hands – which is somewhat different from our current use of the term. These models usually modelled various algebraic surfaces and curves of various degrees, and were wide spread in France and then in Germany during the last third of the 19th century. Although the tradition of construction of material mathematical models slowly declined during the 1930s, when the term 'model' acquired new meaning during the 1920s and the 1930s, signifying procedures of abstraction and mathematical representation of certain well-selected processes, during the second half of the 20th century one sees the emergence of a different kind of visualization of mathematical surfaces: that is, visualizations done with the computer.

Such progression of new computer visualization techniques from the 1970s would be the topic of my talk. For example, in the 1970s, the work of Gaston Maurice Julia was revived and popularized by Benoit Mandelbrot (1975; cf. Samuel 2014). Inspired by Julia's work, Mandelbrot was able to show, with the help of computer graphics, the first images of fractals known today. As computer visualization techniques advanced, these new techniques began to regain their status as epistemic procedures. Among the first breakthroughs in mathematical visualization during the 1980s was proof of the existence of another minimal surface of genus 1, in addition to the flat plane and, the helicoid and the catenoid. While Celsoe Costa discovered the formula for this surface, David Hoffman and William Meeks were developing computer programs to visualize Costa's surface and observe its properties, which were later successfully proved (Hoffman 1987).

In addition, the techniques of three-dimensional printing and interactive computer visualization must also be taken into account historically, as they both underline and modify the role of materiality of the mathematical object. Hence, drawing on, for example, the Costa-Hoffman-Meeks example, the talk aims to show how new digital material practices of mathematical objects (e.g. the construction of a digital surface) intersect with the tradition of model construction of the 19th century, while constituting at the same time a new epistemic visual practice.

Short biographical note

Michael Friedman is a Senior Lecturer at the Cohn Institute for the History and Philosophy of Science and Ideas. The focus of his research is on how material, visual and symbolical knowledge and practices in mathematics interact with each other. More specifically, his research examines the material practices of mathematics (folding, weaving, braiding, knotting, as well as three- dimensional models) and how symbolical-mathematical knowledge was prompted by them.

Visualization, Computation and Mathematics. Images in the Age of the Computer

Janina Wellmann

Max Planck Institut für Wissenschaftsgeschichte, Berlin

Scientific knowledge production has always relied substantially on the production of images, from hand drawings and copper plates to photography and contemporary simulations.

For the last fifty years, computation, engineering and data acquisition have become key to advances in 21st century life sciences. Along with this change in perspective, experimentation and modeling comes a revolution in the visual imagery.

In my talk, I trace the epistemological longevity of visual forms and pictorial conventions to depict the living world. In particular, I discuss visualization practices and changing media and technologies of representation in the field of embryology, physiology or cell biology over the past two centuries. Following the development of microbiology and nanoscopy, I argue that the introduction of the computer into the sciences was accompanied by new conceptions of human perception based on calculation rather than representation.

Short biographical note

Janina Wellmann is a cultural historian of science. Her work spans the history of knowledge about the living world from the early modern period to contemporary science. It encompasses epistemology, media and material practices and uses tools from anthropology, literary and technology studies. Between 2022 and 2024, she is a Visiting Scholar at the Max Planck Institute for the History of Science in Berlin.

The Monte Carlo method and the development of computer graphics

Youssef Abdel Aziz

American University of Cairo & SPHERE, Université Paris-Cité

This project investigates the links between computer graphics, experimental nuclear physics, and mathematics. It aims to understand the circulation of knowledge in these three scientific communities, and to show how this circulation facilitated the development of new algorithms intended to improve image rendering: the process of generating photo-realistic, or non-photorealistic images. More specifically, it highlights how the solution of integro-differential equations, using the Monte Carlo method, played a role in improving computer-generated images.

The Monte Carlo method was invented in the late 1940s by Stanislaw Ulam and John von Neuman. Soon after, the word began to spread about the method, notably in several conferences organized by IBM between 1949 and 1953. In these conferences, the Monte Carlo method found many applications, including solving integro-differential equations of the Fredholm type, which turned out to be of major importance for nuclear reactor shielding calculations in the 1950's that involved integro-differential transport equations of the Fredholm type. The circulation of knowledge about solving integro-differential equations in nuclear physics books became key in their transmission to the field of computer graphics, a field where the problem of image rendering was framed in the language of transport equations in the 1980's, and in particular in terms of Fredholm equations. Hence computer scientists resorted in the context of computer graphics to the same approach used in the context of reactor shielding calculations, namely: the Monte Carlo method to integro-differential equations.

It is worth noting that another 'classical' approach to solve the Fredholm integral equation was developed in parallel to this one, and relied on finite element methods. This approach is less spectacular than the earlier one mentioned though, as finite element methods were widely known for a long time in all engineering fields, and the connections are easier to make. What remains interesting however, is the way different researchers framed the problem in a similar fashion, at the same time, but using two completely different approaches. Understanding the difference between these two approaches and the aftermath of their respective developments, provides concrete examples of the circulation of theorems of mathematics and physics in the field of computer graphics.

Ultimately, this project's relevance to the workshop is that it addresses the following question: how the improvement of computer graphics and hence visualization, and in particular image rendering, is an example in and of itself of practices and knowledge circulating across disciplines in three different scientific fields, namely: mathematics, experimental nuclear physics and computer graphics?

Short biographical note

Mathematical physicist and historian of science. Research Areas (and topics): Mathematical physics (diagonals of rational functions, Feynman diagrams and their links with elliptic curves and hypergeometric functions); history/historiography of contemporary science (transfer of Monte Carlo methods to computer graphics, the reception of Apéry's proof of irrationality, history of diagonals of rational functions); history of Arab and Islamic science (translation of Roshdi Rashed's works on the history of Arab and Islamic science); ethnomathematics (craftsman use of vernacular mathematics in contemporary Islamic Cairo).

The continuity of architectural drawing within early computer-aided experiments: from research to academic experimentation (1960-1990)

Emma Larcelet

École Polytechnique Fédérale de Lausanne (EPFL)

In the post-war years, major American industrial companies saw in emerging electrical and computation research an opportunity to develop visualization tools for mechanical engineering simulation and design. Computer science soon found its way into architecture, and by the 1960s modern mathematics were exploited by North American scholars to experiment and reflect on pioneering computer-aided tools in architectural practice. Driven by a spirit of humanism and innovation, computer visualization enabled the virtual abstraction of physical concepts such as structure and statics, promoting computer-aided-drawing as an intellectual, cultural and technical ideal. As a result, new research departments opened in universities, where the optimization of design became a major focus for previously separated disciplines. The 1980s witnessed the progressive introduction of the computer into architectural schools and practices, stimulating a renewal of architectural language while promising a form of liberation imposed by conventional analog and manual drawing techniques. The practice of drawing, which Renaissance treatises put forward at the center of architectural discipline, was thus transformed, ostensibly challenging the forms of knowledge associated with the production of architectural images.

Therefore, the current research aims to provide a critical reading of this "digital turn" from 1960 to 1990 in an attempt to position architectural drawing practice and its relationship to early aided computation within a continuous evolution of visualization practices throughout history.

The presentation will highlight the initial stages of the research, focusing on the exploration of points of contact and divergences between computation and architecture, asking: Can we establish a genealogy of drawing practices from computer-aided-drawing? North American universities are proposed as case studies to testify the interdisciplinary interaction between industry, teaching and experimentation over the key period. Specifically, the research of the Architecture Machine Group at Massachusetts Institute of Technology (MIT) and Ohio State University will be discussed. Looking at the context in which these visualization tools were introduced, the presentation will address the impact on the reorganization of models of teaching, thought and design. Acknowledging the latent agency of drawing practice, the study will investigate the idea, norms and values conveyed through its computer-based visualization over the key period.

Short biographical note

After training as an architect at the École Polytechnique Fédérale de Lausanne (EPFL), Emma Larcelet is currently pursuing a doctoral thesis, *Analog and Digital: Addressing the continuity of architectural drawing practice in the design process*, supported by the Swiss National Science Foundation (SNSF) and supervised by Prof. Nicola Braghieri, at the Arts for Science Laboratory (LAPIS).

Quantifying flow? About the history of Particle Image Velocimetry (PIV) and how to turn a flow film into a data film.

Mario Schulze and Sarine Waltenspül

University of Lucerne

PIV is an algorithm-based optical flow analysis method that has been developed since the 1980s and is now one of the standard methods in fluid dynamics research. It allows the measurement of the direction and velocity of individual particles in fluids. In our presentation, we will delve into the history of the PIV method. In particular, we will focus on one notable example of its use to analyze how PIV changed the epistemic object of fluid dynamics research and how it rendered flow quantifiable.

Specifically, we will focus on the PIV reanalysis of a 1927 flow film by Ludwig Prandtl, performed by Christian Willert and Jürgen Kompenhans of the German Aerospace Center. Kompenhans himself played a major role in the development of the PIV technique. However, Willert and Kompenhans did not publish the data obtained from their PIV analysis, but instead produced a film entitled "PIV Analysis of Ludwig Prandtl's Historic Flow Visualization Films". In June 2010, they received the Best Movie Award at the 14th International Symposium on Flow Visualization in Daegu, South Korea. And in 2019, in collaboration with us, they re-evaluated film sequences from Prandtl's lab using particle tracking velocimetry (PTV) and Lagrangian particle tracking (LPT), both of which are finer-resolution successor methods to PIV.

These films visualize data obtained by numerical analysis of digitized historical film material. However, the original film shines through the colored areas as a black-and-white background. The superimposition of colored visualized data and translucent black-and-white film corresponds visually to a palimpsest. Willert's and Kompenhans' moving data images are not only a palimpsest of different methods of flow research and media formats (analog film vs. digital scanning), but also of different scientific visual and image styles, and of different historical layers that might allow us to question the relationship between image and calculation.

In our presentation, we will therefore pursue the following questions: How does the interweaving of analog visualization by means of film and the datification of the material, which in turn forms the basis for a computer-based visualization of the flow, take shape? Or to put it more generally: What is the relationship between imagery/aesthetics and computation/calculation?

Short biographical note

Mario Schulze has published on the history of scientific films as well as on the history of exhibitions. He holds a PhD in cultural analysis from the University of Zurich. Post-doctoral appointments took him to the HU Berlin, the Zurich University of the Arts, the ETH Zurich and the University of Basel.

Sarine Waltenspül works on scientific films. She holds a PhD in media studies and is leading a research project on the *Encyclopaedia Cinematographica* in science studies at the University of Lucerne. Previously, she was a postdoc at the Zurich University of the Arts and at the ETH Zurich, and a fellow at Media Cultures of Computer Simulation, Lüneburg.