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A Digital Humanities Approach to Film Colors

Barbara Flueckiger

> And much of the data mining that leads to visualization . . . is based on a flawed method that conflates literal discourse and symbolic/interpreted reference. In an art-historical context, this would be the equivalent of counting instances of the color red across a collection of images without discriminating between symbolic and representational functions. The reds are not the same, and cannot be counted the same way, put into the same category, or re-represented as data for visualization in a graph or chart, without monstrous distortion.
>
> —Joanna Drucker, "Graphical Approaches to the Digital Humanities," *A New Companion to Digital Humanities*

There are strong and justifiable objections to the measurement or, more broadly, the computer-assisted analysis of aesthetic phenomena—as Johanna Drucker makes clear.[1] One pitfall of quantitative analysis is its potential to disregard the meaningful context of data occurrences across the body of works studied. In fact, any quantitative approach to aesthetics that aims to reduce the inherently ambiguous quality of works of art into measurable units runs the risk of engaging in positivist reductionism and of fundamentally ignoring philosophical aesthetics and its analytical tradition. Given these reservations, it may seem extremely bold to investigate one of the most intangible aspects of film aesthetics, namely, film colors, by computer-assisted tools in the emerging field of digital humanities.

Colors are elusive. Our perception of them is deeply influenced by the context of their appearance, their material presentation, the given cultural framework, and each individual spectator's subjective response. However, it was precisely this challenge that led to the development of the projects elaborated and reflected in the digital humanities platform Timeline of Historical Film Colors and, most importantly, the research project FilmColors, which was

funded by an Advanced Grant from the European Research Council (ERC). By their very definition, ERC Advanced Grants are meant to be "high risk, high gain" projects that "are designed to allow outstanding research leaders of any nationality and any age to pursue ground-breaking, high-risk projects in Europe."[2] This article offers insight into the current state of research in computer-assisted film color analysis and applications that are either available or in development.

FilmColors is closely linked to the interactive Timeline of Historical Film Colors, which started in 2012. The platform consists of a comprehensive web resource and online database for all topics related to film colors, with a special focus on their technology, aesthetics, analysis, and restoration. Thus the Timeline is a collection, an archive, a documentation process, and, increasingly, an annotated system for the investigation of the topic, which offers access to a curated body of information to researchers, archivists, film historians, and a broader audience of users from different backgrounds. Four different interdisciplinary approaches investigate the relationship between aesthetics and technical innovation as applied to film colors.

First, the database-driven analysis of film color aesthetics, their affective qualities, and their narrative functions aim to identify diachronic aesthetic patterns. Based on this offline database, the research team is developing a computer-assisted tool with a web interface that will allow the crowdsourcing of film color analyses applying recent advancements in digital humanities and custom-made visualizations. Then these aesthetic analyses are connected to the study of film color technology in combination with chemicophysical analyses of historical color films to understand the influence of film stocks and color processes on films' aesthetic appearance. Third, the team will apply insights gained during the digitization and restoration of historical films by taking into account the requirements of restoration ethics while improving

workflows. Finally, three PhD theses in progress will provide case studies from three periods: the emergence of film colors from early applied colors to so-called natural colors (1896–1930), the development of standards in film color technology and aesthetics (1930–55), and the dominance of chromogenic processes (1955–95).

The project features a truly interdisciplinary approach to consider and connect all the relevant factors—from technology to perception and aesthetics—because they are closely intertwined. The focus remains firmly rooted in the humanities.

Methodology: Stylistic Analysis and Digital Humanities

The planned computer-assisted tool for analyzing film colors derives from the widespread positivist notions of measurable entities in perception proposed in the second half of the nineteenth century by Gustav Theodor Fechner,[3] which had descended from the psychophysicists Hermann von Helmholtz, Ernst Heinrich Weber, and the many other researchers of the stimulus–response relationship. Fechner's approach was shaped by normative assumptions about universal laws on the concept of beauty, expressed most notably in the principle of the golden mean.

In the 1920s, with the advent of abstraction in the visual arts and in film, artists sought to elaborate universal principles for nonrepresentational art. With nonreferential modes of representation, compositional patterns were analyzed with analogies to harmonics in music and the rigorous notational systems that governed their creation and performance. Wassily Kandinsky, in his theoretical writings, *Über das Geistige in der Kunst (Concerning the Spiritual in Art)* and *Punkt und Linie zu Fläche (Point and Line to Plane),*[4] analyzed minute elements of composition to hypothesize universal structural formations of art. In a similar vein, we find analytical investigations in the writings of Bauhaus representatives, such as Paul Klee, Josef Albers, Johannes Itten, and Ludwig Hirschfeld-Mack. Similar attempts were made within avant-

garde filmmaking movements, for instance, Soviet filmmaker Dziga Vertov's strict diagrammatic tools for structuring utopian art.[5] These approaches are role models for analytical classification systems with a strong commitment to qualitative research.

In the 1980s, David Bordwell, Kristin Thompson, and Janet Staiger, in their famous 1985 study *The Classical Hollywood Cinema,* elaborated a triadic model that combined neoformalist analysis, historical poetics, and cognitivist investigation.[6] Historical poetics and neoformalist analysis remain the most important methodological foundations for contemporary film style analysis. Bordwell and Thompson's [1] neoformalist analysis follows methodologies introduced by formalist approaches in art history and the Russian Formalist school that attempted to extract and organize patterns of style *(poetics)* from larger groups of artworks. This method allows for the identification of personal, group, or period styles by applying specific parameters to the corpus of work under examination. Historical poetics connects the observation of these patterns to foundational economical, technological, and institutional frameworks. As Bordwell puts it,

> a historical poetics of cinema produces knowledge in answer to two broad questions:
>
> 1. What are the principles according to which films are constructed and by means of which they achieve particular effects?
> 2. How and why have these principles arisen and changed in particular empirical circumstances? . . .
>
> In place of a bottom-up analysis of a large group of films, historical poetics aims at a broader understanding of "*what* happened, *how* it happened and *why* it happened."[7]

Another strand of this methodology is statistical style analysis, first applied by Vlada Petrić in 1974, and notably by Barry Salt[8] in his seminal investigation into the relationship between technological innovation and stylistic features in film. This approach was then redeveloped and transformed by Yuri Tsivian and Gunars Civjans into a web-based tool, Cinemetrics, to statistically measure average shot lengths (ASL). A crowdsourcing interface has collected measurements on hundreds of films. Both in Salt's analysis and in the Cinemetrics

interface, the obvious shortcomings of a purely statistical method become apparent. Such analyses fail to consider, for example, the effects of a certain camera movement or framing. In contrast to Cinemetrics, the tool proposed in FilmColors is decidedly multidimensional and includes human interpretation to produce significant results that connect the various parameters and observations, as is demonstrated later.

FilmColors is typical of the emerging field of digital humanities, which is not a methodology but rather a set of tools encompassing diverse technologies: from database analysis, textual analysis, and corpus linguistics to the annotation of data, all of which are essentially verbal methods of investigation. These methods are extended visually by video annotation, diagrams, and visualizations or by 3-D mappings and animated computer simulations. Big data processing and evaluation—scraping, crowdsourcing, or geographic information system mapping, to name a few—are inherently digital methods that require access to larger bodies of data collection.

While digital humanities have developed rapidly since the early 2000s—especially in the fields of textual analysis in literary studies, or the historical study of primary and secondary sources—they have not yet been widely implemented in film studies. As Adelheid Heftberger noted, one reason is the sheer complexity of the task.[9] Audiovisual representations consist of many layers of information and are time-based media, which makes the task even more daunting.[10] Several researchers working in the fields of artificial intelligence (AI) and computer vision have stressed the high-level requirements of such tools to extract meaningful entities out of the complex arrangements present in films.

Database-Driven Aesthetic and Narrative Analysis

The research project focuses on material properties of film and the resulting aesthetics—as

expressed in the concept of *material aesthetics.* Therefore great care must be given to the source material. The FilmColors research team aims to focus on the aesthetic and narrative functions of colors in film by analyzing a large group of films. The titles chosen are widely regarded as landmarks of film color aesthetics. They were selected from the results of an online poll featuring more than one hundred canonical films. The poll was completed with a meta study of online listicles that focused on film colors and on [2] the study of monographs on film colors. The resulting canon was then counterbalanced by comparative groups of films that were identified by the study of primary and secondary sources; the works of national film productions, individual filmmakers, or cinematographers; and specific genres, such as musicals, science fiction films, melodramas, and horror films [3]. For practical reasons, the first step of computer-assisted analysis has been executed mainly on films available on DVD or Blu-ray. The results will be checked through photographic documentation with a calibrated camera setup based on the extensive examination of analog film prints in archives around the world.[11]

Researchers initiating a computer-assisted workflow for analyzing film colors must establish parameters defining a consistent grid applicable to a very large corpus of films. Seen from the perspective of theories of representation, film colors can shift between stylization and verisimilitude, structural patterns of pure abstraction, or the suppression of ostentatious modes of expression to achieve a realistic mode of representation. Stylized or emphasized uses of colors—such as in *The Wizard of Oz* (Victor Fleming et al., 1939)—enhance the narrative with sensual richness. These color schemes can be arranged on a continuum ranging from restrictive to gaudy to hyperchrome palettes, based on the relationship, the numbers of hues in a given shot or sequence, and their saturation (Figures 1a and 1b).

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Figure 1a. Restrictive color scheme in *Funny Face* (Stanley Donen, 1957). Image courtesy of the

Academy Film Archive. Photograph of the Technicolor dye-transfer safety print by Barbara Flueckiger.

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Figure 1b. Hyperchrome color scheme in *Gentlemen Prefer Blondes* (Howard Hawks, 1953). Library of Congress. Photograph of the Technicolor dye-transfer safety print by Barbara Flueckiger.

Color contrasts and harmonies are discussed with existing frameworks, first and foremost with the seven types of color contrasts outlined by Bauhaus theoreticians [4] Johannes Itten, Faber Birren, Josef Albers, Albert Henry Munsell, and Wilhelm Ostwald.[12] After identification of the basic color scheme, the compositional arrangement of the colors in patches, lines, or shapes and their dynamics and planar structuring principles are scrutinized on the two-dimensional level of image formation (Figures 2a and 2b).

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Figure 2a. Central deep staging in *The Red Shoes* (Michael Powell and Emeric Pressburger, 1948). British Film Institute. Photograph of the dye-transfer nitrate print by Barbara Flueckiger.

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Figure 2b. Flat ornamental image composition in *Les Chrysanthèmes* (Segundo de Chomón, 1907). Library of Congress. Photograph of the stencil-colored nitrate print by Barbara Flueckiger.

The colors of the mise-en-scène (set design, environment, costumes) and lighting colors have to be taken into consideration. We follow Philipp Otto Runge's distinction between surface colors (Körperfarben) and luminous colors (Lichtfarben).[13] Lighting greatly affects color appearance, because the colors we see are a result of object colors and their interaction with light, their color temperature, and spectral properties. Colored lights are often associated with the moods and psychological states of characters.[14] High-key, low-key, and chiaroscuro lighting schemes were adapted to color cinematography beginning in the late 1920s with the Technicolor Process 3, as in *The King of Jazz* (John Murray Anderson, 1930) and *Doctor X* (Michael Curtiz, 1932).

Object colors, on the other hand—often in conjunction with colors attributed to

characters, their costumes, their hair and skin tones—establish relationships or conflicts.[15] The dominant object worlds in melodramas reflect the conditio humana of the protagonists as an immediate aesthetic experience of their emotions suppressed by bourgeois conventions.[16] Furthermore, color appearance and aesthetics are closely connected to the surface properties of objects and scenes depicted, such as shiny or glossy, tarnished or dull materials, or textures with small-scale variations or coarse patterns. Similarly, the optical transformation by the cinematic apparatus affects the appearance of colors through variations in depth of field or deep focus, lens diffusion, or optical resolution. And the film material influences the appearance of colors with specific shifts in hue, graininess, and flatness versus three-dimensionality. Motion and montage analysis identifies successive patterns of temporal structures and *visual rhyming*—a term proposed by avant-garde filmmaker Hans Richter.[17] For our offline database currently in operation, we developed a detailed system that allows for careful analyses that identify aesthetic developments in certain historical, cultural, or national contexts, considering the associated technical systems.

On the basis of the huge data set that is being collected, the insights will be contextualized with questions about historical, cultural, societal, or technical aspects of colors useful in interpretation and discussion. How did production design reflect trends in consumer culture? How was color cinematography limited or advanced by the technologies? What are the differences in film color aesthetics when we compare, for instance, Technicolor to Agfacolor or Gasparcolor? What were professional discourses and practices within a given production context?

Development and Application of a Computer-Assisted Tool for Analyzing Colors

The tools planned and applied in the FilmColors project require human intervention to produce significant results. Since fall 2016, the platform has utilized a video annotation system called ELAN that enables segmentation of film content and provides several tracks of annotation (Figure 3). Next, the team exports the data from the video annotations into a custom-designed FileMaker database, which includes all the different concepts presented in the previous section. We settled on ELAN after investigating the many video annotation tools that have been developed during the last decade. We based our choice on a survey published by Harvard University[18] and on a lively discussion about users' experiences we initiated in the Facebook group Filmwissenschaft/Film Studies. The four most promising tools were ANVIL, Advene, ELAN, and Lignes de temps. Team member Martin Weiss tested all these systems. Ultimately, our evaluation of video annotation systems revealed a severe lack of sustainability. Most of the tools had been developed within third-party-funded research projects and abandoned when the projects ended or, at best, two or three years later.

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Figure 3. Screenshot video annotation tool ELAN, template used in the research project ERC Advanced Grant FilmColors. Screenshot by Barbara Flueckiger.

The University of Saarland developed the ANVIL[19] software as a tool for video annotation and analysis as part of the research project called Digital Formalism. Advene[20] had the broadest number of features for our purposes, such as shot detection and region of interest annotation in combination with the automatic creation of thumbnails. One of the very few examples of software that contains an interface for analyzing colors is Lignes de temps, from the Institut de recherche et d'innovation du Centre Pompidou, developed for film studies with support from the film historian Sylvie Lindeperg.[21] This certainly is one of the most valuable video annotation systems. It provides RGB values distributed on a time axis. However, it ignores

the aesthetic and narrative dimensions (as outlined earlier) and thus does not provide valid results indicating audience perceptions. It also does not consider the complex relationships between the colors present in differing proportions on the two-dimensional image plane and the sequential unfolding on the time axis. Like most of the other systems, recently it has been abandoned in its initial offline version. A new online version is simplified and requires staff to upload films, which reduces the number to only a few more feature-length films.[22]

For these reasons, we decided to work with ELAN.[23] It was developed for analyzing spoken language but boasts an elaborate user interface and many features. For instance, we take screenshots during the analysis that later may be extracted and inspected with a semiautomatic color scheme extraction tool (discussed shortly). A student assistant developed a template based on our main concepts. One of the most useful functions is the possibility of detaching the video being analyzed from the interface and screening it independently on a second screen. To this end, we installed color-calibrated 4K monitors that allowed working in parallel with ELAN, the FileMaker database, and GraphicConverter software to process the extracted screenshots. However, ELAN also has several serious drawbacks. Most significantly, it was not designed for the aesthetic analysis of feature-length films. Consequently, it has a very limited range of annotation selections in its timeline. It does not offer any of the more sophisticated features present in other systems, such as shot or motion detection, let alone a tool for analyzing color schemes. The main advantages are its stability, the openness of the system to ingest many different types of video codecs (mainly QuickTime files), an easy-to-operate segmentation mode, and the ability to create screenshots and to export the data in many different formats.

For the human-operated, computer-assisted analyses, the team applies a FileMaker database that is easy to customize by project leader and, in the case of any more difficult tasks,

allows for instant troubleshooting by in-house advisor Simon Spiegel. After approximately seven months' experience with the tool, however, we have to admit that the analyses are very labor intensive and time consuming. We reevaluate the tool on a regular basis to reduce its complexity or offer different layers of detail with varying complexity for different users, such as PhD students, the student assistants, or external test users.

Semiautomatic Color Analysis and Visual Representation of Results

The next step in the development of FilmColors will be the semiautomatic extraction of color schemes. This tool's aim is to deliver objective results that complement the other analyses by extending them, either on the macro or meso level. The macro level connects observations made on larger numbers of films; the meso level focuses on whole individual films; and on the micro level, the researchers investigate individual shots or short sequences.

Approaches recently have been developed to detect color schemes or color distributions in films and artworks.[24] For instance, in Data-Driven Film History, the analyses integrated each frame of the film under study into a large picture that, read from left to right and from top to bottom, summarizes the color scheme in one view.[25]

The resulting comprehensive overview renders the color distribution and its temporal unfolding into a plot that provides synchronic information about the entire film at a glance. This approach is especially fruitful for early cinema, which was usually monochrome with tinted and/or toned segments. Other films, however, have very pronounced temporal or structural patterns, such as the ones that assign color codes to different narrative strands or levels of subjective point of view.[26] *Hero* (Yang Zhou, 2002) and *Traffic* (Steven Soderbergh, 2000) are good examples.

Kevin L. Ferguson applied yet another method to his study of Westerns employing the code ZProjector.java. He created visual summaries that layer all the images on top of each other. "Each image in the montage," Ferguson explains, "is a sum image of every 10th second of each film (that is, one frame from every 10 seconds was extracted and summed with the others to create a real image."[27] This method produces a color fingerprint for each film and comparison of the color palettes of Western films.

These images are not only beautiful to view but also useful. By projecting them onto a grid that distinguishes between saturation on the *y* axis and hue on the *x* axis (using the software ImagePlot), distribution patterns become obvious. Ferguson has applied the technique to demonstrate the different color schemes in Disney films, Westerns, gialli (Italian horror films), and Zatoichi films (a series of samurai action films).[28]

Movie bar codes are the most widely used visualization tools and have been presented online for some time (see, e.g., the Tumblr blog created by an unknown cinephile[29]). They apply a sampling method that compresses each individual image or a sequence of images into one pixel on a grid of vertical lines chronologically from left to right. In contrast to ImageJ's method, this averaging completely obscures the visual impression. The movie bar coding process for *The Red Shoes* (Michael Powell, Emeric Pressburger, 1948) elides the eponymous shoes. *The Wizard of Oz,* in contrast, is revelatory when certain segments—most prominently the green associated with the wizard—become instantly visible. James E. Cutting, in collaboration with Kaitlin L. Brunick and Ayse Candan, chose a more sophisticated approach by creating a line for each individual color scheme, arranged from red to blue, for an exemplary analysis of *Inception* (Christopher Nolan, 2010) (Figure 4).[30]

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Figure 4. Color scheme of *Inception* (Christopher Nolan, 2010) depicts the levels of narration.

From James Cutting et al., "Perception, Attention, and the Structure of Hollywood Film," http://people.psych.cornell.edu/~jec7/curresearch.htm.

While it might be valuable to apply all these tools to the corpus investigated in FilmColors, we use our video annotation tool for a more ambitious solution to extract color schemes, similar to Adobe's Color CC. It has a user interface allowing manual adjustments when extracting colors from screenshots or video files. However, as becomes instantly evident in a comparison of different films, Color CC does not do justice to three main requirements. It does not consider the quantitative distribution of hues identified; it does not make a distinction between foreground and background, which is one of the most important types of expressive means in color film aesthetics;[31] and it completely disregards the textures of colors by projecting them onto uniformly colored patches. This is unfortunate, because, as can be seen in films such as *Gate of Hell* (Teinosuke Kinugasa, 1953), *Red Desert* (Michelangelo Antonioni, 1964), and *A Single Man* (Tom Ford, 2009), textures are of utmost importance to film aesthetics. They greatly affect our color perception and convey the protagonist's psychological experiences.[32] As one observer noted in an online forum, color schemes that do not take into account the spatial distribution are like a cooking recipe in which all spices are listed with no idea of the quantities.[33]

The ideal tool thus must apply spatial filtering; that is, it must divide images into patches of similar colors that identify the quantitative distribution of dominant hues. Such tools do exist. There is the Cinemetrics tool by Frederic Brodbeck[34] (not to be confused with Tsivian's Cinemetrics) and the tool by TinEye, which identifies patches of similar hues, measures the percentage of their occurrence, and assigns them color names and a hex code.[35] TinEye, however, defines the constraints for individual hues quite coarsely. In *The Umbrellas of Cherbourg* (Jacques Demy, 1964), for example, although different shades of red play an

important role in characterizing the complicated mother–daughter relationship in the film, the tool collapses them all into one red hue (Figure 5). Hence the tool should be used cautiously regarding different expressive and narrative systems that are connected to individual films' aesthetic repertoires.

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Figure 5. Color scheme extraction from one still of *Les Parapluies de Cherbourg* (Jacques Demy, 1964) with the online tool TinEye (https://www.tineye.com/).

Color saturation and saliency are other noteworthy concepts. The latter, according to Laurent Itti, "is the distinct subjective perceptual quality which makes some items in the world stand out from their neighbors and immediately grab our attention."[36] Similar to Itten's definition of color contrasts, this concept is often tied to both a quantitative and qualitative contrast, drawing attention to a figure, an object, or a part of the environment that may or may not be of narrative importance. The related so-called pop-out effect describes a stimulus-driven bottom-up perception defined by the opposition of a stimulus to its surroundings, be it a regular pattern that is broken or a difference in quality, such as saturation. Regardless of their narrative significance, saturation and saliency direct the viewers' attention to an area in the frame and charges it with a specific aesthetic value. A smart algorithm that models the human response to such stimuli is needed to scrutinize it.[37] The findings could be verified by empirical eye-tracking studies and by human interpretation afforded by the offline analysis tool.

Texture analysis is the next factor to be evaluated. We can apply a concept that Kandinsky and the Russian Formalists referred to as faktura.[38] On the level of representation and image formation, textures result from the profilmic arrangement of environments, objects, or costumes in framing, lighting, and movement. On the levels of film stock and color process, each material is also characterized by its own graininess. Different material properties of film stocks'

graininess may be expressive in their own right.[39] The FilmColors analysis of the first batch of samples (approximately 150 out of the 400 planned) indicates that the legibility of the filmic composition, the surface properties, and textures is highly significant for colors' aesthetic and affective dimensions.

A sophisticated system ideally should integrate recent AI discoveries related to computer vision. AI motion detection devices that have been developed for use in image processing and visual effects could be adapted as filmic tracking systems to annotate temporal unfolding, distinguishing, for example, between character movement and camera movement.[40] In March 2017, we began developing computer vision software for the investigation of the figure–ground relationship mentioned earlier, in collaboration with the Visualization and MultiMedia Lab of Renato Pajarola at the University of Zurich (Figure 6).[41]

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Figure 6. Foreground–background extraction using computer vision. Noyan Evirgen, ERC Advanced Grant FilmColors, in collaboration with the Visualization and MultiMedia Lab of Renato Pajarola at the University of Zurich.

The visualization tool in FilmColors will project color schemes and color contrasts into a perceptually uniform color space that contains all the relevant color and space data similar to the one in the CIE LAB, developed by the Commission internationale de l'éclairage.[42] This color space provides data dimensions, hue, saturation, and brightness that are objective, referring to measurable unities, and perceptually uniform, adjusted to the properties of human vision.

The FilmColors tool will select from these several types of visualizations that compare temporal and spatial color structures for micro-, macro-, and meso-level analyses: single frames, segments, and the entire work (see Figure 7).

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Figure 7. Analysis on the meso level: segmentation and average lightness of *All That Heaven Allows* (Douglas Sirk, 1955). Gaudenz Halter, ERC Advanced Grant FilmColors, in

collaboration with the Visualization and MultiMedia Lab of Renato Pajarola at the University of Zurich.

Integration and Critical Discussion of Results

FilmColors's significance lies in its ability to connect the analyses of the formal aesthetic features to semantic, historical, and technological aspects. Because most analyses of film colors are organized by starting with a semantic and narrative investigation, or by confining their history to technical or institutional perspectives, they often neglect the aesthetic level completely. Once the hermeneutic mode of interpretation sets in, aesthetic features become functionalized and lose their primary sensory qualities. In fact, the dominant mode in color film production and in professional discourses on color in film has always subordinated color to narrative principles. Normative and ideologically charged notions of taste called for the restrictive use of colors in accordance with traditions in visual arts and culturally established conventions.

Symbolic uses of colors referred to such traditions, most prominently following Natalie Kalmus.[43] However, upon closer examination, these second-order meanings are seldom stable. Except for the color red, with its widespread associations of love, blood, passion, and aggression, every other color has different and contradictory meanings depending on contextual, cultural, and historical uses.[44] These meanings must therefore be investigated and questioned, based on studies on the meaning of color in art history, design, and the culture of everyday life.[45] In the silent era, with its applied colors, tinting, and toning, symbolic and stereotypical uses of colors were common. As many scholars have elaborated,[46] except for a few rather stable stereotypical associations like red for fire, blue for night scenes, or amber for interiors, every film should be analyzed carefully to extract the structural functions and narrative meanings of colors.

As mentioned in the introduction, there are valid and strong objections to the reduction of complex aesthetic phenomena to preconceived and rigid data grids. Conversely, there is also a

considerable advantage to being able to translate visual impressions into visually accessible diagrams. Drucker's skepticism does not do justice to one of the biggest problems in analyzing audiovisual representations, which is the severe limitations of language when it comes to investigating and communicating sensory spatial and temporal phenomena. As David Rodowick has commented, every description of moving images lags behind the object of its analysis: "The solid ontological anchoring of a worked substance is grasped only with difficulty, yielding an art that, so far, leans, more than any other, on an experience of the Imaginary."[47]

Visual and diagrammatic representations can be significant epistemological instruments to compensate for the shortcomings of language. While they are never neutral—as critics of such instruments continue to emphasize—they offer important insights not otherwise attainable in the purely linguistic realm. Diagrammatic methods have been a rising topic of scholarly debate, especially within the theory and history of art. Drucker notes that their logic, epistemological underpinnings, and functions have been investigated as "visual forms of knowledge production."[48] Dating back to Charles Sanders Peirce's notion of graphs as operations of reasoning, the productive contribution of diagrams has been a subject of semiotic and philosophical theories of symbolic representation.[49] Sybille Krämer notes, following Peirce, that relationships depicted by diagrammatic iconicity create evidence. They do not show the objects themselves but rather the relationships between the objects and the insights derived from their analysis.[50]

Nelson Goodman underlines the abstract nature of diagrams and schemata, referring specifically to colors to illustrate his position:

> We categorize by sets of alternatives. Even constancy of literal application is usually relative to a set of labels: what counts as red, for example, will vary somewhat depending upon whether objects are being classified as red or nonred, or as red or orange or yellow or green or blue or violet. What the admitted alternatives are is of course less often determined by declaration than

by custom and context.[51]

Visualizations thus depend fundamentally on the underlying classification systems that define them as well as on the corresponding reference system. Each tool should critically reflect its own built-in biases and basic assumptions. Or, as Patrick Vonderau puts it, there is a difference between a soufflé and a muffin tin, regarding not only their specific purposes and functions but also their respective cultural traditions.[52]

The double purpose of diagrams to both visualize and structure knowledge is at the core of FilmColors. We identify patterns by researching perceptual, colorimetric, and aesthetic properties of colors as well as their history in art, consumer culture, and design. Along with their narrative functions, we analyze and contextualize their expressive and affective or emotional values.

The evidence created by computer-assisted analysis and its subsequent visualizations will answer—in Bordwell's words—the question of "why it happened." What were the epistemological assumptions that guided inventions in the realm of film colors? What were the guiding discursive notions in professional practices and in the marketing of film colors' added value? How did the color systems and technical solutions respond to cultural norms of taste in a given period and geographical location? How are color schemes and aesthetic patterns connected to chemical and physical properties of film stocks? As research progresses on an ever-growing group of films, we will get closer to the answers.

Barbara Flueckiger has been a professor for film studies at the University of Zurich since 2007. She is the author of two textbooks about sound design and visual effects. Her recent research projects investigate the digitization and restoration of archival film, in collaboration with archives and the film industry. In 2015, she was awarded the prestigious Advanced Grant by the European Research Council for a research project that investigates the relationship between the technology and aesthetics of film colors (http://www.zauberklang.ch/).

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The illustrations may be viewed in color in the online edition of *The Moving Image,* accessible via JSTOR.

Notes

1 Joanna Drucker, "Graphical Approaches to the Digital Humanities," in A New Companion to Digital Humanities, 2nd ed., ed. Susan Schreibman, Ray Siemens, and John Unsworth (Malden, Mass.: John Wiley, 2016), 247.

2 "Advanced Grants," November 12, 2016, https://erc.europa.eu/funding-and-grants/funding-schemes/advanced-grants.

3 Gustav Theodor Fechner, Vorschule der Aesthetik (Hildesheim: Olms, 1871).

4 Wassily Kandinsky, Über das Geistige in der Kunst, insbesondere in der Malerei (Munich: R. Piper, 1912), and Kandinsky, Punkt und Linie zu Fläche (Bern: Benteli, 1926).

5 Adelheid Heftberger, Kollision der Kader: Dziga Vertovs Filme, Die Visualisierung ihrer Strukturen und die Digital Humanities (Munich: Edition Text + Kritik, 2016).

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