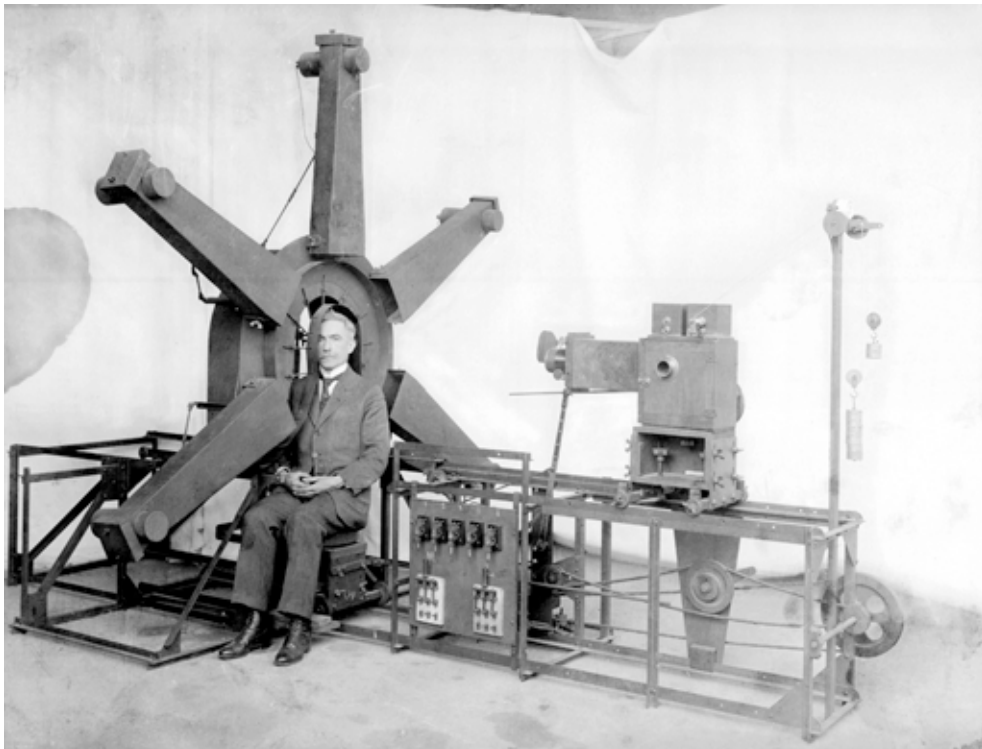


FOCUSING ON FORM— THE FUTURE OF PHOTOGRAPHY

Adam Lowe

The quantity of digital information being generated and the speed at which it can be processed is changing the way we think about photography in all its forms since the digital's superseding of the analogue. So-called 'big data' will continue to grow exponentially and the challenges this presents are being discussed around the world—the attention is focused on what to do with it, how to access and disseminate it, how to store it and ensure it is there for future generations. The technology is developing so fast that its implications cannot be predicted. Many of the issues that need to be addressed require significant shifts in professional and legal structures, philosophical frameworks and technical skills. The ability to generate and process vast amounts of data has triggered a creative revolution that is changing the ways we think on fundamental levels. Thinking back twenty years, the discourse that surrounded digital printing focused on the lack of a physical matrix that could be considered as the master copy—the intellectual focus was on the original plate or negative from which other copies could be made. Today the attention is on 3D printing, the 'third industrial revolution' according to the *Economist* (21 April, 2012).



Early 3D photography system. Claudius and Xavier Givaudan. Courtesy of Musée Nicéphore Niépce, Chalon-sur-Saône.

The photomechanical processes developed in the 19th century led to the explosion of printed images but in the digital age the printed copy is increasingly virtual and the physical print is embracing the third dimension. As a result the future of photography is increasingly concerned with form rather than image—it is 'becoming' a map rather than 'representing' a landscape. It always had this potential and as we study the pre-history of photography we will pay more attention to the various processes that used relief to form the image rather than those that relied on a chemical fix.



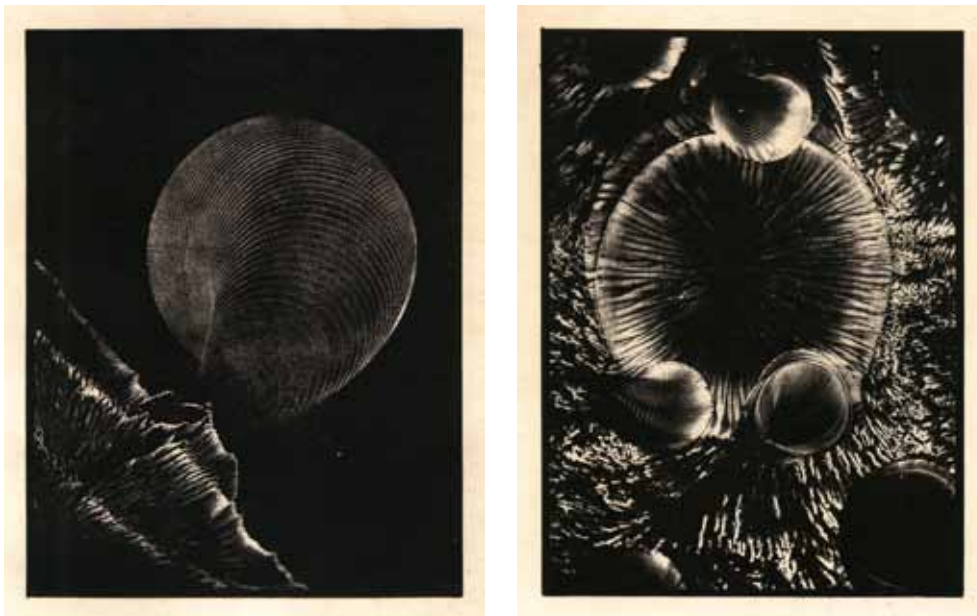
An example of early 3D recording and printing. Layered relief model. Claudius and Xavier Givaudan. Courtesy of Musée Nicéphore Niépce, Chalon-sur-Saône.

Historians of photography have concentrated on the way a group of individuals in the 1830s mastered a series of material transformations that resulted in the conversion of light into tone and the subsequent fixing of greyscale information to produce a stable image—literally drawing with light. But light was not the only thing with the ability to form an image. These lateral and creative thinkers were working at a time when recording images from nature preoccupied many great minds working in many disciplines. Curiosity was the key ingredient and the results of their experiments were generally referred to as “figures”.

‘The most common term in the 19th century for these visual records was “figures”—Lichtenberg figures, Chladni figures, Lissajous figures. Traces of the invisible forces of nature, rendered via the patient enhancement of effect only casually observed earlier, or never seen at all. What we might now call “force figures” and think of as rough maps of force distribution, steps on the way to equations. Not that they look like maps, but like pictures—of electricity or sound or magnetism.’

David Phillips, *Noise* (a series of exhibitions about information and transformation, Cambridge, 2000)

The emphasis was not yet on three dimensions but on how things change and transform—on how electricity, sound and other forces can be visualised. Georg Christoph Lichtenberg (1742–1799) used the patterns that formed in resin insulation to visualise electrical action in the form of Lichtenberg figures. Ernst Florence Chladni (1756–1827) used the vibration generated by drawing a violin bow across metal plates to produce Chladni figures, complex patterns that appeared in sand. Jules Antoine Lissajous (1822–1880) bounced a beam of light off a mirror attached to a tuning fork to produce Lissajous figures. They were not alone—as time passed many others were exploiting the transformation of physical forces in order to visualise the invisible. Margaret Watts-Hughes (year of birth unknown—died in 1907) used vibrating membranes to produce ‘Voice Figures’ and ‘Ghost Figures’. Lord Armstrong (1810–1900) working at his house in Northumberland, (Cragside was the first house in England with electric lighting) with local photographer John Worsnop, discharged electricity across sensitised plates in 1897 to produce photographic images of the invisible forces of electricity.

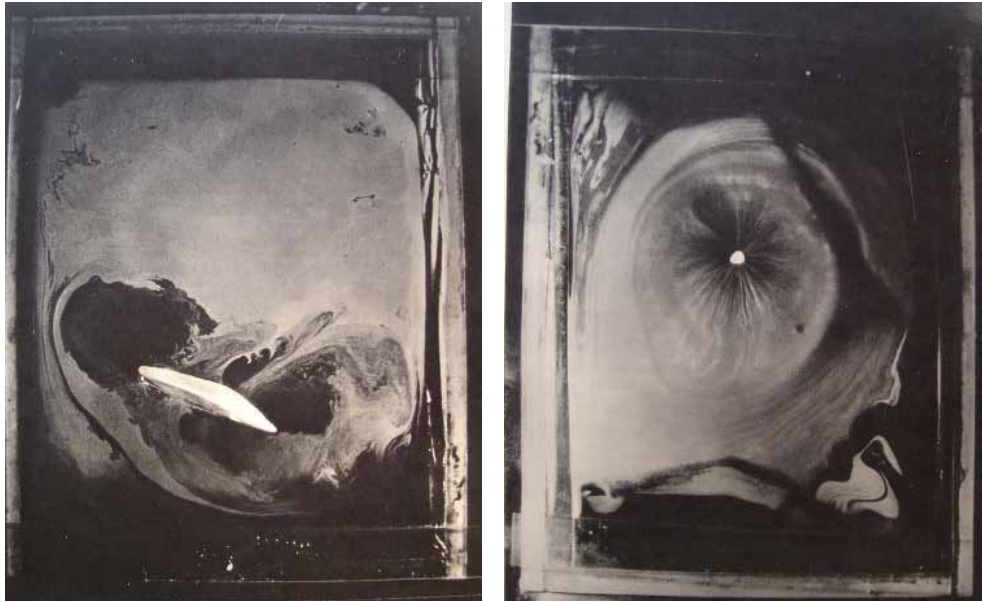


Eidophone Voice Figures, 1891. Margaret Watts Hughes.

Electricity was often the subject but it was also vital in the process of making images. In the Austrian State Printing House in Vienna, under the direction of Alois Auer (1813–1869) pressure, relief and electro-forming were used to produce nature prints (and tactile typography). The ‘nature printing process’ invented by Auer in 1852 is one of the inspirations for many of the ideas articulated here. This process created images of extraordinary realism and physical presence by using the technologies of the time—mechanical pressure to create a relief impression, electro-forming to materialise a physical object (both positive and negative) and intaglio printing to fix a colour image on paper with a physical presence and realistic appearance. In a revised history of printing that places the attention on ‘mediation’ Volta’s creation of the first battery in 1800 will become a more important focal point than 1839, when Hershel coined the term photography, Daguerre produced the Daguerreotype and Fox Talbot perfected his calotype process.

In the synaesthetic digital environment all the senses are equal, but for many years smell was overshadowed by the waves of light and sound. In 1938 a group of photographs were exhibited at the Royal Photographic Society made by F. Breitenbach. They were produced by coating the surface of mercury with talcum powder and exposing it to an odiferous material—the mono-molecular layer of talc was repelled by the volatilising substance that we normally experience as smell to produce patterns of complexity and beauty. The photographs were made to illustrate experiments by Henri Edgard Devaux (1862–1956), a plant physiologist and the pioneer of surface physics. Devaux’s ingenious experiments relied on his intimate understanding of the nature of the physical world.

Until recently the attention of photographers and the broader photographic community focused on the image—but in this text the focus is on the way tone and digital data can be mediated to produce form. Focus is a term that appeared in geometry and physics in the mid-17th century and derives from the Latin word meaning ‘domestic hearth’—the place where people are concentrated—a locality—a single point. With the current conditions of exponentially increasing digital potential and new applications for photography, knowing the location of an exact point becomes the key that can open the door to a new three-dimensional world. Surfaces that used to be flat become detailed volumes in relief. Shape becomes a new world of triangulated polygons and point clouds.



Left: *The smell of a lily*. Right: *The smell of camphor*. Both by F. Breitenbach for Henri Devaux 1930s. The emission of an odor involves volatilisation of material. If an odiferous material is enclosed in a cell a few millimeters above a clean mercury surface, it is possible to collect on the surface of the mercury a monomolecular layer of the volatilising or odoriferous substance. If the mercury surface initially is covered with talc powder, the gradual formation of the monomolecules layer may be observed as the talc is gradually pushed away from the point immediately below the specimen of material.

Photogrammetry is the name given to the science of taking measurements from photographs. Increasingly it is not just dependent on visible light but also on sound waves, radio waves and laser. The history of photogrammetry is linked to the development of perspective and Uccello, Durer and Leonardo all play a role. But as in all good stories unsung heroes and overlooked geniuses emerge. Claudius Givaudan and his son Xavier (1902–1925), whose archives are housed in the Musée Nicéphore Niépce in Chalon-sur-Saône, produced a photo-sculpture machine that used photography to capture relief in the early 1920s. They went even further than this. Once they were able to record and extract an edge they could turn this into a contour line, ascribe it a depth and produce accurate relief portraits. X and Y coordinates can be mediated to produce an image. X, Y and Z co-ordinates can be mediated to produce a form. The algorithms (step-by-step instructions) that mediate the data also condition its character. The more elegant the algorithm, the more the digital form corresponds to the physical world. Mapping is emerging as the new form of realistic representation that is freeing photography from the role of image recorder—just as photography had liberated painting in the mid-19th century. A map is normally seen as a visualisation with a high level of abstraction but it is more fruitful to consider it as information with a high level of condensation. In this context the metaphor of condensation is refreshing. With abstraction the process is one of irreversible loss but condensed data can be expanded back into something resembling its original form.

In 2012 the Grand Palace staged *France en Reliefs* (February 2012), a beautifully mounted exhibition that contained sixteen scale models made so that Louis XIV could better defend and possibly expand his kingdom. Between 1668 and 1873 two hundred and sixty models were made at a scale of 1/600. During the exhibition ‘ordnance survey’ maps of France were laid on the floor of the Grand Palais and as the visitors entered they could be seen orientating themselves and homing in more and more until they identified the small black rectangle that either represented their specific house or identified the features that enabled them to picture the exact place where they lived—or where their friends lived—or where they went on holiday. Cartographic representa-



France en Reliefs, Grand Palace, 2012

tions have the ability to put us at the centre of our world and facilitate a mental reconstruction of the symbols on the map—as a memorable piece of graffiti on a wall beside the railway tracks leading into Paddington station (probably written by Heathcoat Williams) once observed: ‘the far away is close at hand in images of elsewhere’. This is a natural tendency that has been exploited very effectively as a commercial tool by Google. The GIS (Geospatial Information System) data that they are acquiring, capturing and processing is dependent on the principles of photogrammetry. Google Earth has changed the way we relate to our planet. Geography used to be distinct from chorography but now the study of the planet and the study of the local share the same tools. The term chorography was introduced by Ptolemy to differentiate the local from the ‘far away’ in geography. It is a term that is finding a new lease of life as the divide that separates the micro and the macro is compressed.

Long range scanning technologies use Sonar, Radar, Lidar to map large areas at resolutions of up to a few hundred points a meter. Close range laser and white light scanning can record hundreds of millions of points per square meter—data of this accuracy can meaningfully record the subtle undulations on the surface of paintings. Gigapixel stereophotogrammetry facilitates the acquisition of vast amounts of high-resolution colour and 3D data. Both specialised 3D software and image processing software applications are being used to move the data between two and three dimensions and communicate with a whole host of ingenious output devices that can print layers or volumes. Additive and subtractive prototyping systems now inhabit print studios alongside photographic, inkjet, UV and laser printers. The new 3D printing processes have their own magic—SLS (stereolithography) hardens liquid resin by the action of light. Sintering uses various methods to form a solid mass from a powder, fused deposition modeling deposits small quantities of various materials to build the object, seven axis routers mimic the complex movements of an arm to carve forms of great complexity. Many things can be ‘printed’ including metals, ceramics, foods, plastics and synthetic materials, organic materials, concrete and body parts.



Top: Facsimile of the Tomb of Tutankhamun, Luxor. Bottom: Scanning process of the Hereford Mappa Mundi with the Lucida scanner developed by Manuel Franquelo and Factum Arte.

The task of bringing all these technologies together means that people have to work in teams pooling knowledge, skills and problem-solving abilities. As a result, a workshop like Factum Arte in Madrid is involved in designing and building the 3D scanning systems from scratch, writing the user interfaces and software, building flatbed printers, making and coating the materials, milling with 3 and 7 axis systems, 3D printing both in-house and with specialist companies and handling all stages of the mediation and transformation that can result in exquisite objects made from noble materials. Curiosity is again a vital ingredient but the ability to communicate between professions that normally struggle to understand each other is essential.

The work done in Factum Arte is inherently varied and diverse but some themes are emerging—the dominant one is the ways in which 3D recording methods and 3D output systems are reshaping the way we think about making things. They are resulting in a radical rethinking of the layout and functioning of the workshops. The following three examples articulate the cross-fertilisation that characterises the new relationship between image and form:



Marina Abramović, routed in alabaster from Fuentes del Ebro.

Marina Abramović: tone and form merge in a block of alabaster

In 2012 Marina Abramović came to Factum Arte with a specific request— she wanted to find a way to make a physical object that captured her presence but was both permanent and ephemeral. By nature *performance* is ephemeral: after the event what remains are memories and still or moving images. The black and white films of the *performances* show the artist held in tone on film. The images come alive when they move in front of projected light—visual traces of intense experiences. A close collaboration over several years took this seed of an idea and gradually gave it form. The conversion of greyscale images into relief data is one of the cornerstones of much of the practical research that is being applied to both 3D scanning and digital printing in Factum Arte. Tone can be transformed into relief by ascribing depth to the greyscale. It can then be processed in different ways to produce an image or a 3D form—or both. The continuous tone process of Woodburytype printing (developed in 1864 by Walter B. Woodbury) is an early example of the inter-changeable nature of tone and form. A Woodburytype print is made by exposing a sensitised gelatin film under a photographic negative. The gelatin hardens in proportion to the amount of light. The unhardened gelatin is washed off in warm water to produce a three dimensional positive. While still wet and swollen the gelatin is stamped into a sheet of lead to produce a negative impression. This is then used as a mould to transfer pigmented gelatin onto paper. Gelatin swells greatly when wet allowing for the subtle replication of a wide range of tones from black to white. As the transferred gelatin dries onto the paper the relief flattens to give the Woodburytype its unique character. It was the only photo-mechanical process to use true tonal values rather than converting the tone into a screen or reticulated pattern.

A black and white image of Abramović was treated in a similar way but rather than stamping under great pressure it was mechanically carved. Black was ascribed a depth of five centimetres and white was nothing. All the steps on the greyscale in between were allocated a depth between zero and five centimetres depending on their tone. Initially this information was routed using a CNC machine into blocks of plaster that were specially prepared with a blend of tones from black to white—black at the bottom and white at the top (the deeper the cut the blacker the tone). But as the idea developed it seemed a more elegant solution to use light to create tone. Blocks of alabaster were sourced in Fuentes de Ebro, near Zaragoza. They were routed with the XYZ data to produce a landscape of relief information. With the light source in front the relief of the surface dominates but with the light source behind the tonal information reads more strongly than the surface to produce an ephemeral image in a physical block of

stone. It is an image that provokes a strong response of attraction and repulsion. As a physical tonal image it is a compelling re-materialisation of the artist, but at the point when the image and the relief fight for supremacy something perceptually strange happens—your mind struggles to read both image and form at the same time—the life and death of Marina Abramović, an ephemeral performance in a block of stone.



Still Life, Manuel Franquelo, 2015. Print on aluminium coated with gesso.

Manuel Franquelo: Focus stacking compressed onto a flat plane

Manuel Franquelo's new composite photographs of his studio also address the nature of perception and shift between two and three dimensions but they are on a flat gesso surface covered with pigment and wax. Advances in computer vision technologies and composite photographs are playing an important role in application of photography to 3D image capture and the work done by Franquelo as engineer, software writer and artist is revealing exactly what can happen when an artist uses all the tools at their disposal. Focus stacking is one of these tools. Wikipedia describes focus stacking as 'a digital image processing technique that combines multiple images taken at different focus distances to create an image with a greater depth of field than any of the individual source images.'

Franquelo has produced vast digital data-sets by using a computer controlled pan and tilt head (with mechanical modifications and software written by the artist) to record the interior of his studio at high-resolution on many different focal planes. The images are aligned across each plane and then merged. The software stitches the images together in perfect register selecting only those with pin-sharp focus. This approach can be used to produce relief images (so called 2.5D images) or to produce images devoid of the normal blur produced by an out of focus object. This method is commonly used in macro-photography and microscopy where the depth of focus is very limited but at the other end of the scale can also be used in astrophotography. It is less commonly used on a scale of 1:1.

Franquelo's new works are still-lives in the Spanish tradition of Juan Sánchez Cotán (1560–1627) and Francisco de Zurbarán (1598–1664). They push the bounds of observation in a way that forces us to reflect on our point of view and our perspectively-limited assumptions. Google Earth enables you to home in on a single location anywhere in the world but these images question the nature of reality and representation. Mimesis (a perspectival notion of reality) was a highly-prized quality in ancient Greece and the ability to transform pigment or marble into something that could convince the eye and the brain was the greatest proof of artistic skill—art and technique went hand

in hand. Franquelo is an artist who is literally taking this to new levels. His tools are not paintbrushes and pre-prepared paints; they are the mechanical and electronic systems he builds, the algorithms he writes, the pigment printers he makes. His interest has always been how the physical world is transformed into a representation of itself and how through many mediated actions it becomes something we can respond to anew.



Portrait of Daniel Wolf in alabaster, 2015. Data from facial 3D scanner and routing process.

The Factum chorographic scanner: Many images to produce one form

One of the main aims of sculpture since the zenith achieved by the ancient Greek craftsmen has been to produce an objectively accurate three dimensional depiction of a human face in a block of stone or in a noble metal like bronze. The technology available now makes this possible.

Multi-view photogrammetry is an approach that works by generating a 'feature map' from many high-resolution images identifying exact points that are stable from different viewpoints and under different lighting. Once these points have been fixed it is possible to build a 'neighbourhood map' that relates each point to each other point. From this map it is possible to extract information about shape and surface. The resolution of this information is dependent upon the number of cameras used to obtain the information, the image quality and the algorithms embedded in the software used to extract the 3D data.

The aim of this 'facial' or 'chorographic' scanner (designed and built in Factum Arte by Manuel Franquelo Jr. with Pedro Miró and Enrique Esteban) is not only to record the

exact shape of a head but also to record surface detail down to the pores and blemishes in the skin. Using multi-view photogrammetry the data can be prepared as a dense point cloud or as a triangulated mesh (the main area of the face is formed from over seven million polygons). The system has been constantly modified and improved over a period of almost two years. The design and construction rely on many purpose built elements but the cameras are commercially available. A vast number of cameras are normally required for accurate multi-view photogrammetry, making the systems very expensive. The positioning of the cameras and the control of the lighting is critical to extract detailed 3D images.

The main innovation of the Factum scanner has been to mount eight cameras onto a moving bar so that multiple shots can be taken in rapid sequence—a facial scan takes just over a second while a full head scan can take about three seconds. Specially designed and manufactured flash units are mounted inside two hemispheres to provide the minimum amount of light to produce a good exposure and uniform flat illumination (it is essential that there are no shadows concealing surface information). The light level is kept intentionally low so that the sitter can be scanned with their eyes open. In all recording the relationship between information and noise is critical and needs to be understood. Hair presents a real problem that is still being addressed, as the noise can exceed the information producing an incoherent surface. In the recording of the eyes the relationship between noise and information has resulted in an interesting artifact that resembles the solution devised by classical sculptors—a slight relief on the iris and a deeper relief on the pupil. The object that emerges challenges our preconceptions—a clear sign that something new is taking place. Things never stay the same—movement is intrinsic to perception.

These three examples illustrate some of the ways in which photography is being used to record form. Walter Benjamin's essay 'The Work of Art in the Age of Mechanical Reproduction' has conditioned the way we think about photography and reproduction but it cannot account for the new paradigm shift that is taking place in a digital age of fast computers and big data. Benjamin observed that mechanical reproduction of a work of art represented something new. He was writing the first version of this essay in 1936, almost one hundred years after the accepted date for the discovery of photography and at a time when mechanical reproduction was well established and shaping aesthetic and political thinking. He observed that works of art exist in their specific time and place and that they reflect the ways they have been valued and looked after. To articulate this materiality he turned to the nebulous and quasi-religious idea of an aura. To prove its existence he could have commissioned electrographs or other methods to visualise this invisible force as a 'figure' but in the age of digital reproduction originality and authenticity may not be as separable as Benjamin had assumed. The digital revolution is moving so fast that it is hard to foresee its many implications. Only a few years ago the focus was on virtual technologies—now the physical has taken centre stage. In this physical environment photography is no longer just producing images, but making maps and charting previously unimagined destinations.