P. Janssen, P. Loh, A. Raonic, M. A. Schnabel (eds.), *Protocols, Flows and Glitches, Proceedings of the 22nd International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2017*, Paper 94 (Preprint). © 2017, The Association for Computer-Aided Architectural Design Research in Asia (CAADRIA), Hong Kong.

INTRODUCTION

A productive ambiguity: diffraction aberrations as a template for the architectural surface

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Abstract. The hi-resolution imaging of public urban space for both promotional and surveillance purposes is now undertaken by a range of ubiquitous visioning technology such as Internet webcams, drones (UAV's) and high-altitude aircraft cameras. The ability to control and manipulate these types of images is a growing concern in an increasingly 'envisioned' environment. One approach is to disrupt or modify the 'emission signatures' of urban surfaces, which requires an understanding of the digital algorithms used to assemble and transmit image content into grids of visual data. Recent scaled tests show that Fraunhofer diffraction algorithms can interfere with the smooth transmission of image data. When these algorithmic patterns are physically constructed into a building façade, they create natural disruption glitches in the camera's successful transmission of visual data. The paper details how the quantum of visual aberration in the digital portrayal of the city can be determined by algorithm-based façade patterning.

Keywords. Surveillance; camoufleur; envisioned; algorithms; diffraction; façades; aberration.

Internet webcams, camera drones (UAV's) and high-altitude aircraft cameras now produce hi-resolution imaging of urban space for a range of promotional and surveillance applications. From the camera-shy industrialist to the military camoufleur, the ability to control and manipulate these types of images has become the preeminent concern of an increasingly 'envisioned' environment. Central to the viewed target's 'bag of tricks' therefore is the ability to exploit techniques by which to disrupt or modify the unwanted 'emission signatures' from a building to overhead observation. The enhanced effectiveness of any intervention in these transmissions must involve methods by which to modify the multispectral signature production of the image, the rapid deployment of the technology and low cost of the deployment of these systems.

One approach to this type of technological intervention involves the use of diffraction or lens flare algorithms to interfere with the smooth transmission of image data. Recent scaled tests show that when these algorithmic patterns are physically constructed into a building façade they create procedural glitches that disrupt the camera's successful transmission of visual data. This not only ensures that the ambiguity of the target remains intact across the global digital image platform, but in so doing, it transforms a perceived 'flaw in the system' into a productive tool.

Glitch, from the Middle-High German glitschen: 'to slip', is becoming a more widespread phenomenon in a media-dominated world. Commonly defined as a brief fault within an electronic system, it is now emerging as a discrete digital art movement that '...explores imperfection by producing or saving unwanted images.' (Joachim, 2005). This subtly worded distinction between 'producing' and 'saving' is, however, crucial to the determination of the glitch's conversion into a productive architectural tool. By drawing upon the notion of the pure glitch 'the result of a Malfunction or Error' rather than the glitch-alike '(to) produce and create the environment that is required to invoke a glitch and anticipate one to happen' (Moradi, 2004), any architectural application of the diffraction effect is immediately endowed with all of the unexplored properties and potential effects of the electromagnetic spectrum. Put simply, it is precisely because the Fraunhofer diffraction effect is a naturally occurring phenomenon, that its application is not delimited by artificial constructs or facsimiles.

Using the results obtained from recently conducted scaled tests, the paper will therefore show how the translation of different Fraunhofer diffraction patterns into architectural surfaces can operate as disruptive camouflage patterns to camera reception. These new prototypical camera responses demonstrate how orchestrated façades can be strategically designed to create precise modifications to the way in which a digital camera receives and disseminates visual data. Erroneously termed 'impediments' to digital production, the paper will detail the precise conditions and parameters by which façade can be designed to magnify the degree of visual aberration in the camera's reception of a building. The ultimate point of this discussion will be to demonstrate that these patterns provide a broad range of productive ambiguities and opportunities for the designer to intercede in the digital portrayal of the city.

1. The camera view: between concealment and surveillance

In her work on the scale and levels of pixel data within the satellite image, Laura Kurgan (2013) reveals how image intensity and contrast data can be precisely indexed to situated events (Figure 1). The pervasive time-lapse recording of the planet by a French SPOT satellite imaging system reveals images of mass war graves in Kosovo in 1999. In this scenario, each pixel has an address expressed in longitude and latitude that corresponds with a unique location, and each reveals the heat value of that place at the time the image. With this type of pervasive aerial scrutiny operating and with a camera resolution of a single pixel equaling 10 square metres, there is little opportunity for data to remain undisclosed.

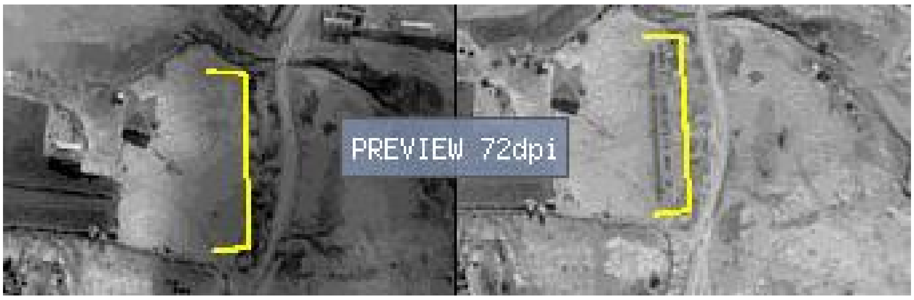

Figure 1. Satellite images showing (left) no graves present and (right) evidence of a massacre and a disturbed grave in Izbica, Kosovo, 1999, taken at an altitude of 822 kilometres.

As terrorist activities become a growing global concern, defence-related camouflage tactics are increasingly concerned with the broader surveillant capabilities of foreign target acquisition systems. Military-based research to date has led to the development of highly complex, cumbersome techniques that require the generation of live ‘counter-data’ (Kitson et al, 2016), but to make land facilities invisible in remote combat locations. However, security-related operational centres are increasingly situated in dense urban zones, thus introducing a need to disrupt or diminish the data content transmitted to unwanted multi-spectral reconnaissance from UAV’s and high-altitude aircraft cameras.

Past research on camouflage tactics at a built scale has focused on the painted application of pixelated patterns to military buildings (Larson, 2013; Robinson, 2012; Baušys & Danaitis, 2010). In these cases, camouflage is only operational within a narrow band of the electromagnetic spectrum visible to the human eye. More recent military approaches to building camouflage now incorporate tactics that attempt to respond to either space-based or airborne hyperspectral imaging technologies that capture both spatial and spectral (infrared) information (Kitson et al, 2016; Snaper, 2006; Manolakis et al, 2003; Reynolds & Kinsella, 2002). Yet these techniques remain highly complex and cumbersome, requiring the generation of ‘counter-data’ for invisibility (Kitson et al, 2016), or to put it simply, they produce a different camouflage for different backgrounds. Consequently, effective camouflage needs to satisfy a broader range of requirements that includes the capacity to produce a spectral match to multispectral or hyperspectral remote-sensing instruments as well as less technical infrastructure and low cost (Blake, 2007; Shaw & Burke, 2003).

In a completely different arena, the highly competitive car industry has developed a means of concealing its latest features. Entitled “Brick” camouflage, Ford has produced vinyl camouflage stickers, which are “uniquely” applied to each vehicle to disrupt the ability to distinguish new exterior features in sunlight, both by human perception and by camera. Tailored to multiple environments, the patterns are designed to disrupt the integrity of the vehicle’s shape, surfaces and colour by delaying the brain’s recognition ability. (Figure 2) While easily deployed and low-cost, the functionality of this solution is nevertheless limited to only a narrow band of the visual spectrum.

Figure 2. Ford test track camouflage

2. Glitch: 'pure' or 'alike'

While delineating a contextual understanding of the perceived and real effects of cyberterrorism, Peter Krapp draws a clear distinction between its perceived and real effects, or in other words, between authenticity and artifice.

'To take the real threats of cyberterrorism seriously is certainly not alarmist, but it is irresponsible not to distinguish between a Net sit-in and the failure of an ATM network, between conceptual Net art and attacks on a hospital generator...' (Krapp, 2011)

Krapp dismisses the bulk of 'hacktivism' as the minor, impotent resistances to existing government and private network systems. These attacks exploit 'the processing rhythms of certain system resources' and 'are nothing more or less than digital demonstrations' (Krapp 2011, p. 51).

The recent emergence of the electronic glitch as a digital art phenomenon presents an interesting parallel to Krapp's words. Glitch artist Tony Scott's website instructs users in one of either two ways: 'Wait for something to go wrong, or force something to go wrong if you're a busy full-time glitch professional' (Scott). The conversion of the accidental into the deliberate does indeed produce examples of complex network 'errors' that seemingly have immense aesthetic appeal. However, the 'forced' glitch, unlike the accidental or pure glitch, is the product of direct intervention and, in that respect, it does not belong to an indexical system. Because it is the facsimile of an aberration or error and therefore theoretically not repeatable, it cannot populate itself by drawing upon a repository of naturally occurring variations of itself. In this respect, while being unique it is also limited - it is another version of a 'digital demonstration' (Krapp 2011, p. 51). Diffraction, on the other hand, is a naturally occurring and repetitive phenomenon within the vast system of optical science. The distinction here is that diffraction is a naturally-occurring error between two independent systems that, in this case, are deliberately rather than accidentally brought together. There is no human intervention within the error process itself. Furthermore, the field of optical science invokes a vast array of diffraction effects when brought into play with the camera mechanism that are quantifiable and able to be endlessly repeated.

3. Fraunhofer diffraction and the aberrations of digital technology

Diffraction occurs throughout the camera's aperture range when a beam of light is partially blocked and split by an obstacle commonly known as a diffraction or transmission grating and, in this respect, it is part of a know indexical system. Diffraction gratings cover the ultraviolet, visible and infrared spectra (Palmer 1995). The presence of these visual aberrations in captured camera data, while known, cannot be controlled and they occur regularly as a result of different climatic conditions, such as rain or fog. (Figure 3). Fraunhofer diffraction is formed by internal diffraction on the image sensor mechanism of the camera when the scattered light falling on the sensor exceeds the range of luminance that can be accurately measured by this mechanism. (McCann, 2007) Camera response functions are tuned to perform in low-contrast, uniformly illuminated scenes specifically to avoid an optical overload or what is known as 'glare spread function' (McCann and Rizzi, 2007). However, despite manufacturers' attempts to control the image-making process and product, these aspects of the camera's function acting in conjunction with light remain unpredictable and uncontrollable.

Figure 3. Figure 3: Fog acting as a diffraction grating on a building façade. (This image is available at: http://www.sharenator.com /Some_Cool_Pictures/).

4. Disruptive surfaces

A series of practical tests were designed to investigate how far-field diffraction grating patterns, or Fraunhofer patterns, as one of the known effects of optical science, could be deliberately used to disrupt camera protocols. The patterns were selected from digital image-processing procedures algorithms with the ultimate intention of constructing a façade based on selected pattern at a magnified scale. This would force light falling onto the camera's image sensor mechanism to scatter and make it behave like a diffraction grating. It is worth noting again note here that unlike the 'forced' glitch whose construct is a single or 'one-off' facsimile of a network error, this instead deliberately draws upon a naturally occurring and repeatable collision between the system of optics and the camera mechanism. A further objective of the tests was to observe the effect of the 'mirrored' grating patterns in conjunction with the f-stop increments of the camera. This would potentially provide a vast array of interrelated effects for an architectural surface, which could be deliberately calculated and applied by referencing the data obtained in the test.

Five Fraunhofer patterns were selected. Three were derived from the camera's internal data-scanning or raster-scanning procedure, a fourth was based on the Human Visual System (HVS) comprising hexagonal elements (Deering 2005), and a fifth, random non-digital pattern was used based on the randomly generated type referred to by Cantoni et al (2011) (Figure 4). The Fraunhofer patterns were created using the open-source software *Fresnel Diffraction Explorer* and a Fast Fourier Transform algorithm. The tests were conducted using a Sony SX43E Handycam digital video recorder, comparable to the Kintronics long range IR PTZ surveillance camera (2014) Both cameras have CCD sensors, which use interlaced scanning, and both have a zoom capacity of 60x.

Figure 4. Left to right: Standard horizontal raster scan-order pattern; Standard horizontal raster scan-order pattern in a 45° rotated orientation; Recursive Z scan-order pattern; Hexagonal, HVS-based pattern; Random or non-periodic pattern.

The diffraction gratings were cut from 2mm opaque black acrylic squares and then placed individually in front of an American DJ FS-1000 Followspot with a ZB-HX600, 120V 300W halogen lamp to simulate the building light emission conditions that would operate at night within an urban context. The camera was placed at two different distances from the image plane: 8 metres and 5 metres. The light source was located directly behind the image plane at a distance of 0.5m. This represents a scaled approximation of the standard Internet camera viewing distance from a brightly lit image source where a relative scale of 1:10 operates, i.e., the 8m image plane distance in the test correlates with an 80m distance in an exterior environment, and so on. Similarly, the grating elements used were 500mm2, correlating with a typical building façade element of 5m2. The aim of this was to enable specific features of the recorded image to be tabulated in accordance with the camera's aperture range or f-stop increments acting in conjunction with its zoom trajectory.The results of the individual patterns were processed using *ImageJ* and *HyperCube2* analysis tools. *ImageJ* analysis was used to assess both the number of unique colours produced and the luminosity emission of each pattern. Because the objective was to see the effects of the diffraction grating upon the camera's image-processing function, the quantum of unique colours produced by each grating along with the luminosity (brightness) of each was critical to the assessment of the amount of disruption to the camera. Accordingly, for each grating pattern, the image at the high end of the camera's aperture or f-stop range was selected to observe the number of diffraction artefacts present (the number of unique colours being directly linked to the effects of diffraction), because this is the point at which these are most likely to occur. *HyperCube2* was used to provide the static and dynamic display of the image cube and to determine the hyperspectral effects of the patterns.

5. Test results

The tests showed that digital-based Fraunhofer diffraction patterns deliver extremely strong brightness artefacts that become more exaggerated as the camera zoom factor increases. Of these, the Fraunhofer pattern derived from the horizontal raster scan-order pattern in a 45°-rotated orientation produced the highest number of diffraction artefacts. This was evident in by the number of unique colours that each of these diffraction patterns produced as seen in the *ImageJ* montage in Figure 5, the addition of all images within the inward and outward zoom trajectory of the camera. Other digital-based Fraunhofer patterns also produced significantly more brightness artefacts than non-digital patterns.

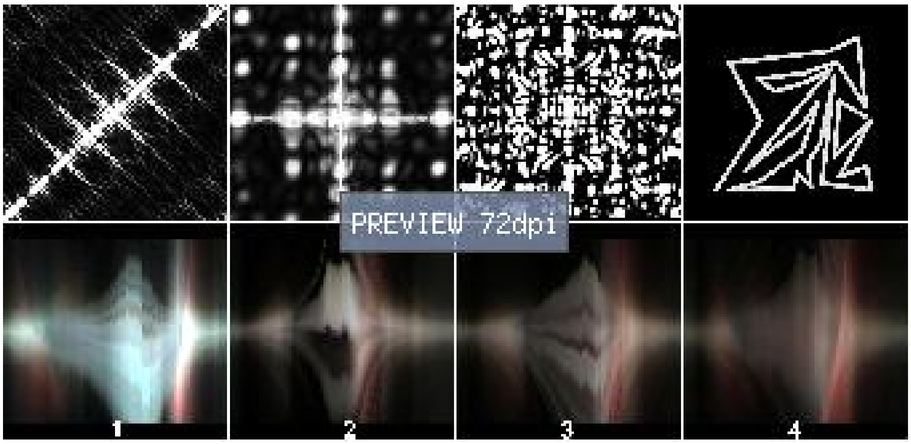

Figure 5. ImageJ test images showing the total disruptive effect (the sum of all images in the camera trajectory) of digital diffraction patterns (images 1-3) upon camera reception over a range of different camera apertures. Image 4 on the right demonstrates the lesser disruptive effect of a non-digital pattern.

HyperCube2 tests showed the hyperspectral effects of the Fraunhofer patterns. Figure 6 below shows the high level of camera interference produced by the use of this pattern as a hypothetical building surface. The tests showed that the use of a magnified Fräunhofer diffraction pattern as a perforated screen, backlit and attached to a building surface, can transform it into a diffraction grating screen that radically modifies image legibility across multiple spectra.

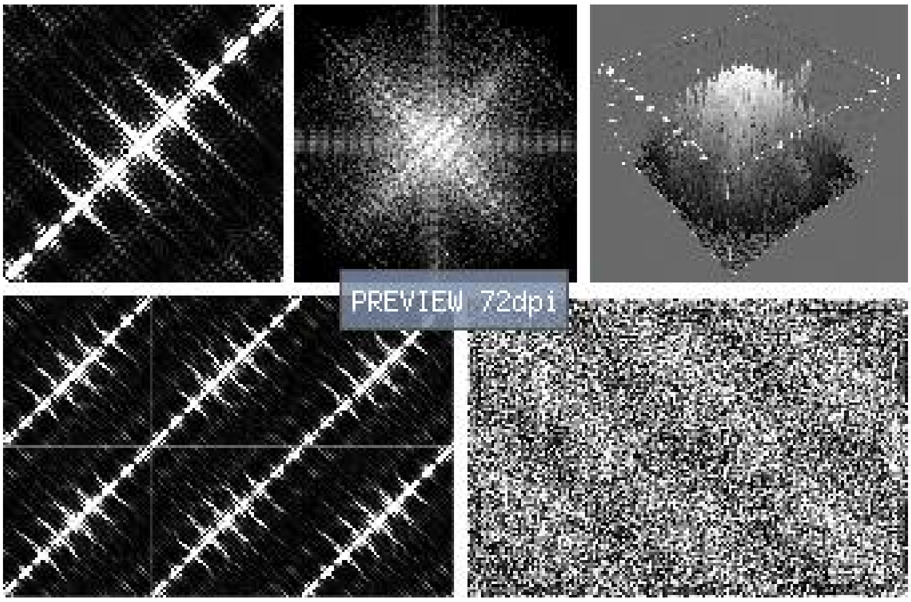

Figure 6. Top left: Fraunhofer pattern extrapolated from a digital raster pattern; Top centre: Fourier transform of pattern from HyperCube2 showing power spectrum of the embedded image using log compression and the high amplitude of the frequencies comprising the image; Top right: ImageJ 3D visualisation of the pattern's luminance surface plot showing extremely high levels of emissivity. Bottom left: Montage of Fraunhofer pattern assembled as a modular array for a building surface.Bottom right: The proposed effect of this array upon camera reception calculated using HyperCube2 software.

Materialised as a series of modular, milled or routed screens covering the entire building surface, these super-sized diffraction grating patterns are a cost-effective way in which to disrupt the clean transmission of visual data. The patterns can be manufactured as a system of 1m2 detachable units, which can be cheaply manufactured and easily assembled into arrays for any building surface. As modular units, they are also easily flat-packed and transported to any location.

Figure 7. Left to right: Fraunhofer pattern extrapolated from a digital raster pattern transformed into a modular screen; assembled screen seen in elevation; hypothetical application of screens to a building surface.

6. Conclusion

The reconsideration of the glitch within an architectural field thus raises issues of productivity and agency. Its transformation from a perceived 'systemic flaw' to a productive architectural tool is possible when it derives its complexity and diversity from the interaction between two independent systems, one electronic and the other of applied mathematics. In this respect, the applied effects of Fraünhofer diffraction allow the designer to draw upon an endless array of physical possibilities.The tests show how new prototypical camera responses open the opportunity to configure façades to orchestrate a natural collision between an existing physical system and the way in which a digital camera receives and disseminates visual data. By showing how the physical application of these patterns can be customized to suit the specific camouflage requirements of any context, they reveal that a building's programmatic activity can be comprehensively masked according to an endless array of possibilities. The specific intention to magnify the degree of visual aberration in the camera's reception of a building thus aligns this work with a newfound agency that, by reinforcing the ambiguous, allows the designer to continue to intercede in the digital portrayal of the city.

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