

# The Spaces in Between

Ceccato Rudy

An exegesis submitted to Auckland University of Technology  
in partial fulfilment of the requirements for the degree of  
Master of Creative Technologies (MCT - AK1307)

2014

Faculty of Design and Creative Technologies, Colab

## **Contents**

<b>Attestation of Authorship</b>	2
<b>Abstract</b>	3
<b>List of Figures</b>	4
<b>Technical Aspect of the moiré Phenomenon</b>	5 - 11
The moiré effect	5
A Brief History of Moiré and its Study	7
Graphical Representation of the Moiré Effect	8
Monaural/Physical Beats	9
Binaural Beats	9
Monaural or Binaural?	10
<b>Positive and Negative</b>	12 - 17
The Notan	12
Bridget Riley and Op Art	15
<b>Moiré Aesthetics</b>	18 - 25
Relevant approaches to the study of moiré	18
Moiré Index	21
Moiré and Sound	22
<b>Conclusion</b>	26 - 27
Presentation	26
Approach to Sound	27
More Than Meet the Eyes and Ears	27
<b>Refereces</b>	28 - 30

**Attestation of Authorship**

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

CECCATO RUDY

A handwritten signature in black ink, appearing to read 'Rudy Ceccato', with a stylized flourish at the end.

## **Abstract**

This exegesis reports the approach and describes the various aspects involved in the realization of a project submitted for the Master of Creative Technologies at Auckland University of Technology.

The project focuses on the moiré phenomenon. The moiré effect is a naturally occurring phenomenon and has been known to many cultures for hundreds of years. Despite of this, most people nowadays still do not know what the phenomenon is, even though they experience it on a regular basis in everyday life. They encounter its many manifestations, but dismiss and ignore them.

The main intention of the project is the creation of a toolset in the form of a software application for aiding towards a better understanding of the moiré phenomenon. The aim is to make such application available to the general public and in doing so to increase the focus on this particular phenomenon. This will help the user of the application to better understand and appreciate the moiré effect, through a process of discovery via visual and aural stimulation. Literature regarding this phenomenon has therefore been researched and studied and steps has been taken for the recreation of this effect in a controlled environment, through both an empirical and theoretical approach.

Visual and aural manifestations of the moiré phenomenon have been considered and used in the creation of the application. The moiré phenomenon is essentially a manifestation of the interaction of positive and negatives. This have lead the research into the study of the eastern philosophy of the Yin and Yang and through this path into the study of certain design techniques that deals with opposites and that requires some degree of sustain meditative visual and aural concentration.

Although of a practical nature, the research have considered various aesthetic approaches to the use of the moiré effect in art.

The initial part of the paper deals with the more technical aspects of the project, with brief explanations of the moiré effect and of monaural beats. This part can be skipped and the reader can return to it on a later stage. This paper assumes a basic level of algebra. Conclusions about the state of the project and its necessary improvements are drawn at the end of the paper.

## Lisit of Figures

Figure 1: a) superimposition of two identical line-gratings with one slightly rotated and the resulting moiré. b) Enlarged detail of the same. (Amidror, 2009, pp02)	5
Figure 2-5: The still images above and below are taken from a video shot by the author of this paper and demonstrate an everyday occurrence of the moiré phenomenon on a superimposed set of curtains.	6
Figure 6: angle view of a visual impulse after Fourier transform, showing its geometricallocation and amplitude. (Amidror, 2009, pp12)	8
Figure 7: graphical representation of the different stages of the moiré effect and the corresponding Fourier-transform analysis. (Amidror, 2009, pp14)	8
Equation 1: F1 and F2 are the two initial frequencies	9
Equation 2: The actual beat's frequency	9
Figure 8: Graphical representation of a monaural beat generated by the interaction of two sine waves and the corresponding visual moiré generated, in this instance, by superimposing two combs with teeth of different spacing.	11
Figure 9: One of many representations of the symbol of the Yin and Yang. (Bothwell & Mayfield, 1991)	13
Figure 10: Example of Notan, 'negative keys'. (Bothwell & Mayfield, 1991)	13
Figure 11: Other Notan examples: bird decoration on plate by Pueblo Indian and 17th century Japanese sword guard. (Bothwell & Mayfield, 1991)	13
Figure 12 - 19: sequence of pictures from the three-step NOTAN exercise	14
Figure 20 & 21: Works by Bridget Riley; <i>Descending</i> (1965) and <i>Movement in Squares</i> (1961) emulsion and tempera on board respectively.	15
Figure 22 - 27: More examples of works by Bridget Riley. From top-left clockwise: Red With Red (2007, oil on linen, the artist herself is portraied with the painting), Current (1964 emulsion on board), Vein (1985, oil on linen), Zing01 (1971, cryla on canvas), Cataract III (1967, emulsion on canvas) and Blaze I (1962, emulsion on board).	16
Figure 28: Anoka Faruquee <i>P-30</i> (2012, acrylic on canvas)	19
Figure 29: Anoka Faruquee <i>P-49</i> (2012, acrylic on canvas)	19
Figure 30: Liz Deschenes Moiré #6 Moiré#7 (both 2007, UV laminated C-Print)	19
Figure 31: Liz Deschenes Moiré #25 (2009, UV laminated C-Print))	19
Figure 32: Linda Basemer, <i>Swoop-WaveBulge01</i> , (acrylic on canvas)	20
Figure 33: Linda Basemer, <i>Swoop-WaveBulge02</i> , (acrylic on canvas)	20
Figure 34: James Cousins, <i>pl.58</i> (oil and acrylic on canvas)	20
Figure 35: Edward Ruscha, <i>Pure Ecstasy</i> (shellac on moiré rayon)	20
Figure 36: Reginald Neal, <i>Red Circle</i> (Lithograph)	20
Figure 37: Reginald Neal, <i>Red Moiré on Blue</i> (Lithograph)	20
Figure 38: Richard Anuszkiewicz, <i>Deep Magenta Square</i> (acrylic on panel)	20
Figure 39: Alvin Lucier, extract from the score for Canon	23
Figure 40: Raster-Noton logo	24
Figure 41: Ryoji Ikeda album cover for <i>Supercodex</i> (2013)	24
Figure 42: Screen shot of application used during research stage for the sonic part of the project.	25
Figure 43: Screen shot of full-screen display of the interactive application at its current state as a Java Applet.	25
Figure 44: Screen shot of part of the Processing code used for the application.	25

## The moiré effect

“The moiré effect is a well-known phenomenon which occurs when repetitive structures (such as screens, grids or gratings) are superimposed or viewed against each other. It consists of a new pattern of alternating dark and bright areas which is clearly observed at the superimposition, although it does not appear in any of the original structures.” (Amidror, 2009 pp 01) The interaction between the two transparent or semi-transparent layers creates the moiré effect. It is the result of the geometric superimposition of the dark and bright areas: the area where the dark element overlap will appear brighter than the zone in which the dark elements fall between each other (thus filling the area, see figure one below). This can be experienced in everyday life, for example if looking to a regular pattern through a chain-link fence, if we stare at a set of curtains waved by the wind or if we are watching fabrics with specific patterns on a television or digital screen.

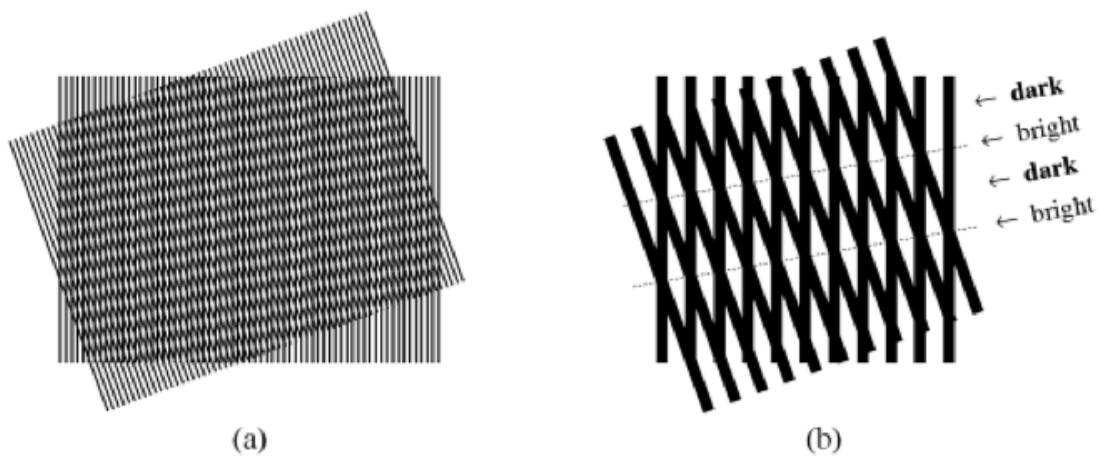


Figure 1: a) superimposition of two identical line-gratings with one slightly rotated and the resulting moiré.  
b) Enlarged detail of the same. (Amidror, 2009, pp02)

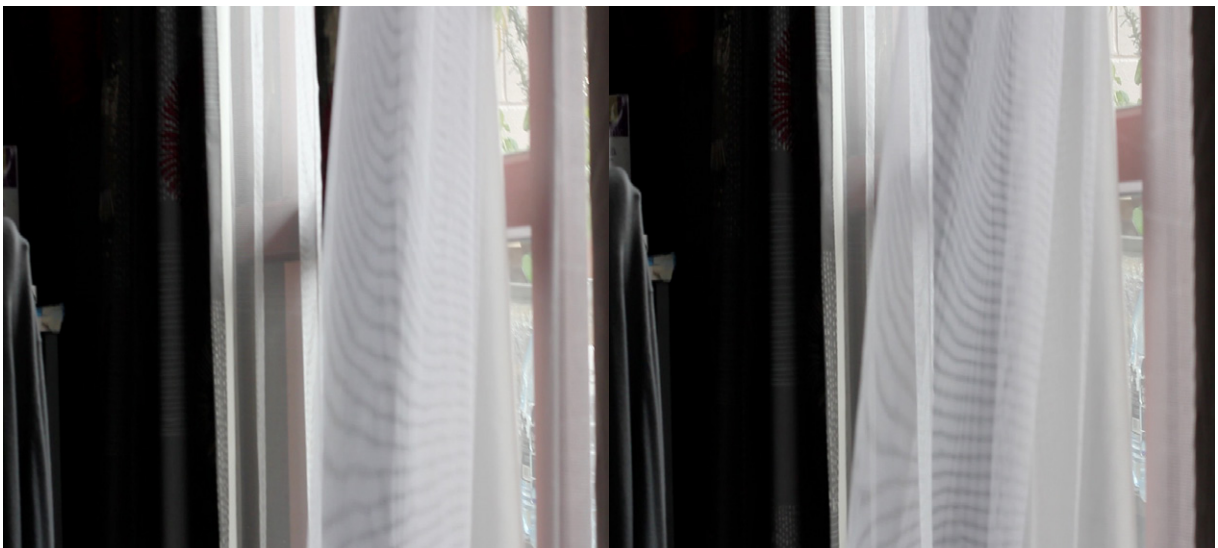
The moiré phenomenon is very sensitive to the slightest variations or movements in any of the two layers. For this reason, it has found a wide number of applications. It is used to identify deformations in objects like lenses, in detection of buildings displacement and to measure stress resistance of materials such as concrete and steel. The moiré effect is also used in crystallography and in document anti-counterfeiting. Additionally, it has found more engaging uses in art and graphic design, as it is described elsewhere in this paper.

However, the moiré effect does not have only positive application. Before specific precautions and efforts were taken, the moiré phenomenon was feared in the printing field, particularly in dot-screen colour image reproduction, where the manifestation of the effect would drastically corrupt the end result.

The digital video and digital photography industry, in particular work intended for broadcasting, can also be negatively affected by moiré artefacts. The advent of high definition video and the implementation of specific software algorithms have reduced the extent that the moiré effect has on digital videos and still images.



Figure 2-5: The still images above and below are taken from a video shot by the author of this paper and demonstrate an everyday occurrence of the moiré phenomenon on a superimposed set of curtains.



## A brief history of moiré and its study

“The term moiré comes from the French ‘watered’ and ‘shimmering’, where it originally referred to watered silk, a glossy cloth with wavy, alternating patterns which change form as the wearer moves, and which is obtained by a special technique of pressing two watered layers of clothing together. Note that the term moiré does not refer to a presumed French physicist who studied moiré patterns.... therefore the term moiré should not be written with a capital letter.” (Amidor, I., 2009 pp 01) Even though the naming of the phenomenon is attributed to the French, the first record of deliberate use of the moiré can be traced back to ancient China where it was used to create moving, dynamic patterns in silk fabric. It took a few thousand years for science to seriously begin to investigate into this phenomenon. Modern scientific research into the moiré effect started only in the second half of the nineteenth century.

For a hundred years since, the approach to analysis of the phenomenon have been based on a geometrical-algebraic method, as can be also noticed in most contemporary research work of Emin Gabrielyan and Yasunori Nishijima (Gabrielyan, 2XXX and Nishijima, 2XXX) or in Carsten Nicolai own research that culminated in the book moiré index.

More recently, during the sixties and seventies, emerging new mathematical theories have been implemented towards a better theoretical investigations of the moiré effect. Of these theories only Fourier-based analysis techniques<sup>1</sup> have contributed to major advancements in understanding the phenomenon. Such implementation of Fourier analysis has been executed in two stages: firstly through the use of Fourier series decompositions for representing the superimposition, secondly through Fourier transformation to convert from image to spectral domain.

Without going too much in details, for the intentions of the project an analytical approach using Fourier theory will prove essential as it enables for a better understanding of the spectral properties of the images used and of their resulting moiré effect, allowing to examine such images from the perspective of both the space domain and, in particular, from the frequency domain. The standard approach used by many researchers studying the moiré phenomenon has been to start from simple cases such as the superimposition of periodic structure such as cosinusoidal (wavy) patterns and then move on to more complex shapes such as binary gratings, grids and dot-screens. A similar approach has been implemented in this project.

---

1) A set of analytical tools mostly used in engineering and mathematics. The name derives from seventeenth century French mathematician Joseph Fourier, who first introduced the basic concepts from which these analysis techniques derived.



## Graphical representation of the moiré effect

The graph of an image that has been analyzed through a Fourier transform is represented by two or more graphical impulses which manifest three properties: an index, corresponding to the impulse position in the Fourier series, a geometric location (or impulse location, the frequency of the impulse) and its amplitude. (see figure two below for a better understanding)

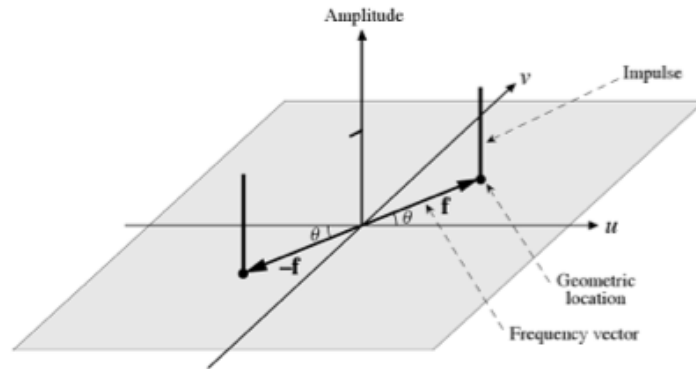


Figure 6: angle view of a visual impulse after Fourier transform, showing its geometrical location and amplitude. (Amidror, 2009, pp12)

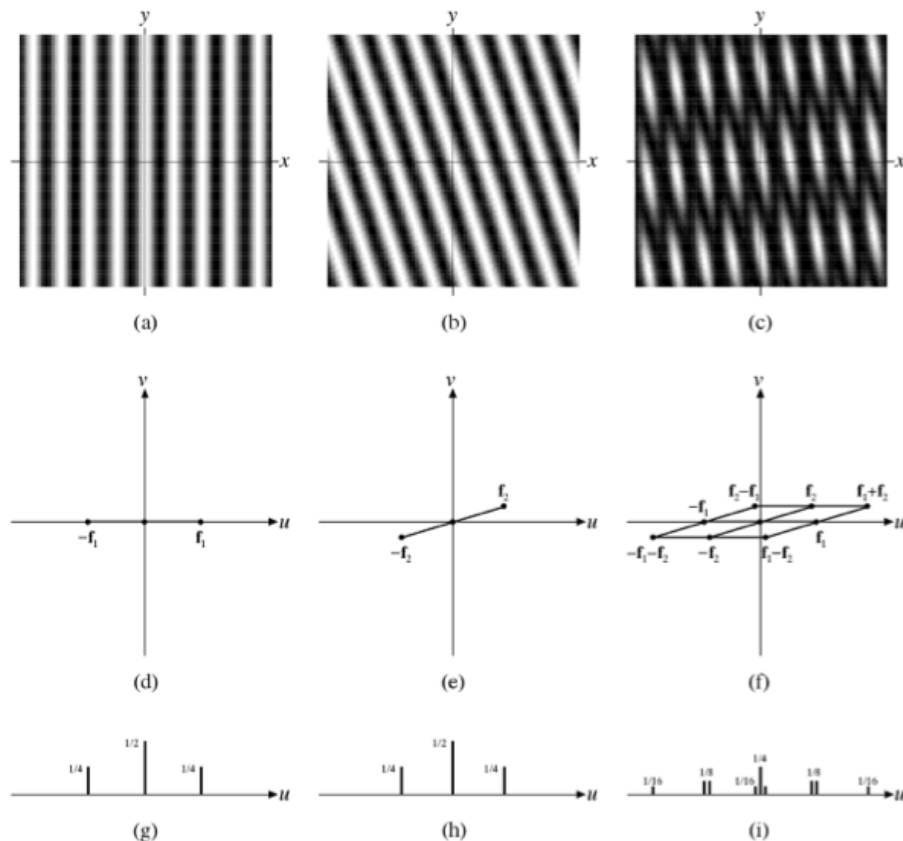


Figure 7: graphical representation of the different stages of the moiré effect and the corresponding Fourier-transform analysis. (Amidror, 2009, pp14)

The figure above graphically displays the three stages of a Fourier-based analysis applied to two different gratings images. The top row shows the two images and the resulting moiré from their superimposition in the image domain. The second row is a top view of their representation in the spectra domain, the “black dots in the spectra indicate the geometric location of the impulses, the line segments connecting them have been added only in order to clarify the geometric relations.” (Amidror, 2009 pp14). The last row is a side view of the same spectra with emphases on the frequency and their amplitude.

## Monaural/physical beats

Monaural beats occur when two simple, pure tone<sup>2</sup> sounds are close together in pitch, but not at the same frequency. When these two sounds are played together, a listener will perceive an additional fluctuating tone which is the result of the two initial sounds interacting with each other. The amplitude and frequency of the new sound is determined by the frequency and amplitude values of the two original sounds. As these two sounds are slightly different in frequency and therefore have different periods, their phases relationship will gradually change.

When the two sounds are summed together via their interaction, this gradual shift of phase will create regions of alternated reinforcement and cancellation, producing a perceived amplitude fluctuation of the resulting, third frequency. This change in phase will repeat over time, reproducing a tremolo-like effect on the overall amplitude envelope of the new sound. The rate at which the amplitude of the new sound fluctuates is the difference between the frequency values of the two original sounds, as in the formula below:

$$\text{Rate of Oscillation of Beat} = | F1 - F2 |$$

Equation 1: F1 and F2 are the two initial frequencies

The actual frequency of the new sound is the mean of the two frequency. As described in the next formula:

$$F_{\text{beat}} = \frac{F1 + F2}{2}$$

Equation 2: The actual beat's frequency

Monaural beats are a common phenomenon for musicians and are used by professionals to tune pianos and guitars. This fact is most likely the reason why they were discovered as early as 1707 by Joseph Sauveur (Johnston, 2002 pp105) and extensively documented by Giuseppe Tartini in his musical treaty of 1754.

## Binaural Beats

Binaural beats are a sonic phenomenon similar in principle to monaural beats, but that actually differ remarkably from each other in terms of the medium where they come to life. For this reason binaural beats are often confused with monaural beats, however they occurs solely within the auditory system in the brain and are strictly related to "interaction in the nervous system of the neural output from each ear". Therefore they are a neurological phenomenon, unlike monaural beats which are a physical event that is produced when "the two tones are mixed in an electrical or acoustical system". (Moore, 2012 pp 252)

Consequently, binaural beats are better experienced via headphones and manifests as a sound swirling left and right between the ears within the stereo field created by the headphones.

Additionally, monaural beats can be experienced across the whole spectrum of audible frequencies, while binaural beats are essentially a low frequency phenomenon. The detection of binaural beats is also dependent upon a narrow frequency range limitation: they seem to be best perceived when the frequency difference between the two sounds (or variance) is of less than about 2 Hz. On the other hand, monaural beats work well within a variance of 10Hz.

---

2) Sine waves, the simplest form of sound, consisting of one single frequency.

## Monaural or Binaural?

It is for these two reasons (spectrum range and frequency variance) that it was decided to primarily focus on monaural beats. The initial intention was to use binaural beats as the sonic equivalent to be pair to the visual. The reason for this choice was because they work exclusively if the listener is wearing headphones. This characteristic also fitted the initial plan to implement binaural beating with a single sound played on each separate earpiece, as the method of presentation chosen requires the use of headphones. Having the two sounds played separately on each ear is also the ideal set up for the implementation of binaural beats. However, further testing and experimentation revealed the limitations that binaural beats display and that were mentioned earlier. It was thus decided to employ monaural beats instead. Through trial and error, the ideal set of parameters to use for the implementation of monaural beats was determined. For monaural beats to work at their best, sounds with matched amplitude had to be employed. This would ensure that a consistent strength of the resulting beat would be achieved, so that the beats effect would always be present. Moreover, three main features for an ideal implementation of monaural beats in the context of the project were identified. Two of these features were introduced previously and are the actual frequency and the rate of amplitude fluctuation of the beat. These two aspects are important as they can potentially influence the way in which the visual matches the audio.

The third feature to be considered was to decide if whether or not it was beneficial to include the possibility of selecting different types of waveform for the two main sounds. The choice of sound waves to use was: sine, triangle, saw and square. From various literature sources and through experimentation, it was established that sinusoidal sounds (sine waves) were best suited to reproduce monaural beats. The use of other types of sound waves led to various unwanted outcomes, producing aliasing<sup>3</sup> artifacts due to oversampling and becoming more noise-like. It is true that moiré patterns can be seen as a form of noise, however, for the purpose of the research, the sonic part was kept as simple and clear as possible.

The same necessity for clarity on the audio side influenced the decision during this testing phase to 'hide' the original two frequencies from the listener. This required the beats to be synthesized within the application, so that the final output, what a listener would actually hear, would only be the beatings. In doing so, the person experiencing the work would have the opportunity to fully focus on the created frequency, the artefact itself. This idea, however have been discarded as the phenomenon itself would lack effectiveness if only one sine wave would be heard.

---

3) Aliasing is a phenomenon in which a sound that exceed the playback system's sample rate caused the generation of frequency components that do not belong to the original sound but that are indistinguishable from it, essentially adding a noise component to the original sound.

The illustrations below show, in sequence, the generation of monaural beats from a graphical perspective. First we notice the two original frequencies playing together, next we zoom into a short segment of the two superimposed waves (about five periods) and examine in more details the amplitude interaction of the two frequencies. The fourth image illustrates the amplitude envelope and frequency of the resulting new sound, the actual beats. Finally, it is possible to notice the correlation between acoustic beats and the corresponding moiré pattern generated by two aligned combs with slightly different teeth spacing/period. This specific moiré instance, where the lines are parallel, is the only one that would work with monaural beatings formed only by two sine waves. Other moiré patterns require a more complex sonic representation produced via FFT analysis. All images from: "Measured Tones: The Interplay of Physics and Music" Ian Johnston.

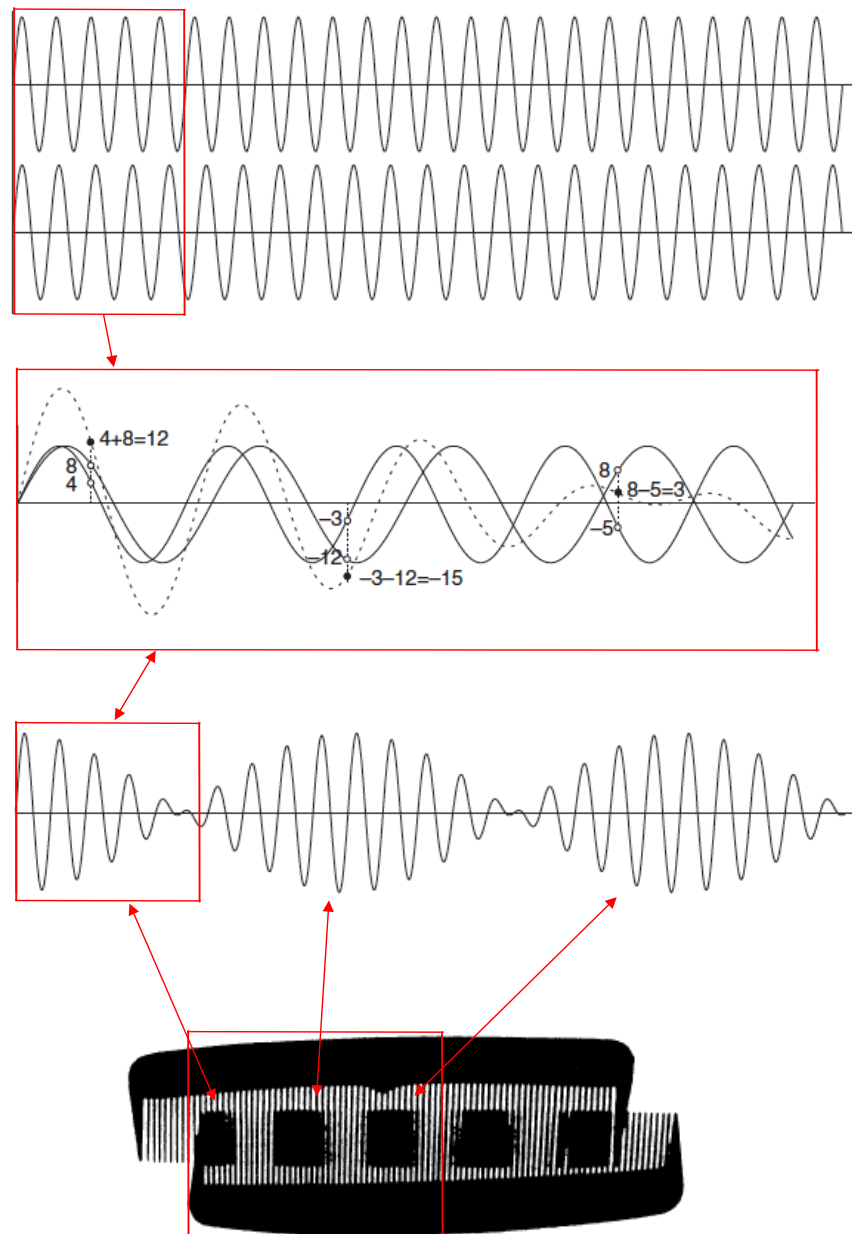


Figure 8: Graphical representation of a monaural beat resulting from the interaction of two sine waves and the corresponding visual moiré generated, in this instance, by superimposing two combs with teeth of different spacing.

W e p u t t h i r t y s p o k e s t o g e t h e r a n d c a l l i t a w h e e l ;  
b u t i t i s o n t h e s p a c e w h e r e t h e r e i s n o t h i n g  
t h a t t h e u t i l i t y o f t h e w h e e l d e p e n d s .

W e t u r n c l a y t o m a k e a v e s s e l ;  
b u t i t i s o n t h e s p a c e w h e r e t h e r e i s n o t h i n g  
t h a t t h e u t i l i t y o f t h e v e s s e l d e p e n d s .

W e p l a c e d o o r s a n d w i n d o w s t o m a k e a h o u s e ;  
a n d i t i s o n t h e s e s p a c e s w h e r e t h e r e i s n o t h i n g  
t h a t t h e u t i l i t y o f t h e h o u s e d e p e n d s .

T h e r e f o r e , j u s t a s w e t a k e a d v a n t a g e o f w h a t i s ,  
w e s h o u l d r e c o g n i z e t h e u t i l i t y o f w h a t i s n o t .

L a o T s e

This ancient Chinese poem wrote about two thousand years ago highlights one of the pillars of Chinese philosophy: the concept that opposite elements found in our lives are interconnected and interdependent. The interactions between positive and negative, light and dark, white and black, hot and cold, day and night, are parts of a mutual whole where one does not exist without the other.

This interaction creates a dynamic system where opposite complement each other in harmony, as represented by the ancient symbol of the Yin and Yang. In such a system this symbol represents the perpetual balance created by the interchanging of the dualities mentioned before and of many others found in nature. As the sun shifts across the sky, the shady slope of the mountain (Yin) becomes the sunny slope (Yang) and vice versa. What was obscured is revealed and what was revealed is obscured. Such a concept is in opposition to the Western's view about life and nature, where opposites do not complements each other but rather struggle against each other to achieve supremacy.

In this culture of opposed dualities, good or evil are moral values that get attached to ideas, concepts, objects and everyday life situations.

### **The Notan**

It was in the context of Eastern philosophy that the ancient design technique of Notan was born. Notan<sup>4</sup> is the word used nowadays to define a design technique that is considered the basis of all good design. It is based on the idea of the Yin and Yang, the energy exchange of negative and positive. The Notan exploits the relationships between the full and the empty, between the black and white. It began in indigenous cultures as an ornamental technique and found its way in modern time as a design necessity. If we think of a pair of scissors, their usefulness lies with the sharp blade, however it would be almost impossible to use them correctly without the holes for the fingers. These were essentially a design feature required by utility rather than by aesthetics. As for most modern commercial design, decoration is an afterthought.

On the contrary, early forms of Notan were inspired by nature, and approached as an intuitive representation of the surrounding world unbiased by modern design rules and regulations, but driven by the indigenous craftsman's primordial impulse for symbolic decoration.

However, like the simplicity of the Yin and Yang symbol represents the more complex notion of the interchange of energy in our lives, Notan is not simply a design technique, but a way of perceiving things, a way of viewing the world from a different perspective.

It reveals the daily swift of forces at play on the stage of life.

The method with which this techniques was approached was through a series of design exercises. One in particular lead to the recognition of the Notan.

---

4) Japanese term meaning dark-light.

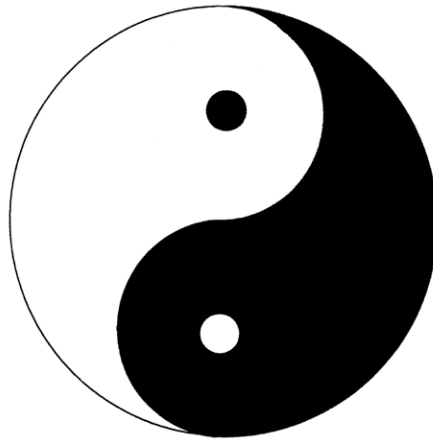


Figure 9: One of many representations of the symbol of the Yin and Yang. (Bothwell & Mayfield, 1991)

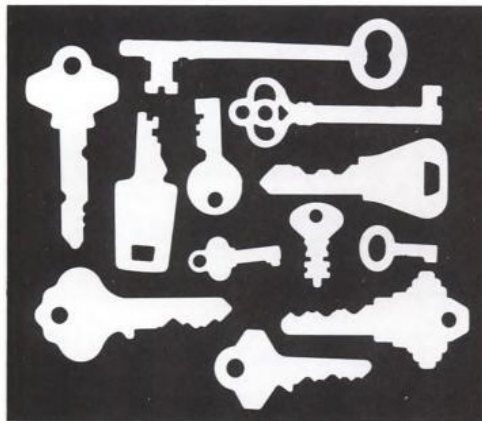


Figure 10: Example of Notan, 'negative keys'. (Bothwell & Mayfield, 1991)



Figure 11: Other Notan examples: bird decoration on plate by Pueblo Indian and 17th century Japanese sword guard. (Bothwell & Mayfield, 1991)

This particular three-step exercise requires the preparation of a white paper 'canvas' of specific measures and of five shapes cut from black construction paper. The shapes have to be of the same type, circles or squares for example, but they have to be in five different sizes. The first step is to arrange these shapes between the boundaries of the frame such as to create an asymmetrical balance, where the viewer attention would continuously shift from one area of the collage to another.

The second step is to hang the work on a wall and view it at a distance of at least eight feet. In viewing the piece from a distance we now have to begin considering the black shapes no longer as weights or things but as holes, or no-things. It might help, for example, to visualize them as holes carved into a piece of wood. "This visual exchange, the perception of a shift from things to no-things, from no-things to things, is characteristic of Notan." (Bothwell & Mayfield, 1991 pp21) This shifts of perspective might lead to the rearrangement of some of the shapes. The third phase is to look at the work again after some time and to imagine that the shapes are no longer holes, but rocks in still white water. Some rearrangement might occur again. The final aim is to create a balance where the shift from negative to positive spaces (and vice versa) will no longer be possible as both elements (the black shapes and the white space) will be equally important, equally present.

This is the Notan.

The images below show some of the various steps in the composition process for the exercise, displaying a sequence of the gradual shift and rearrangement of the elements.

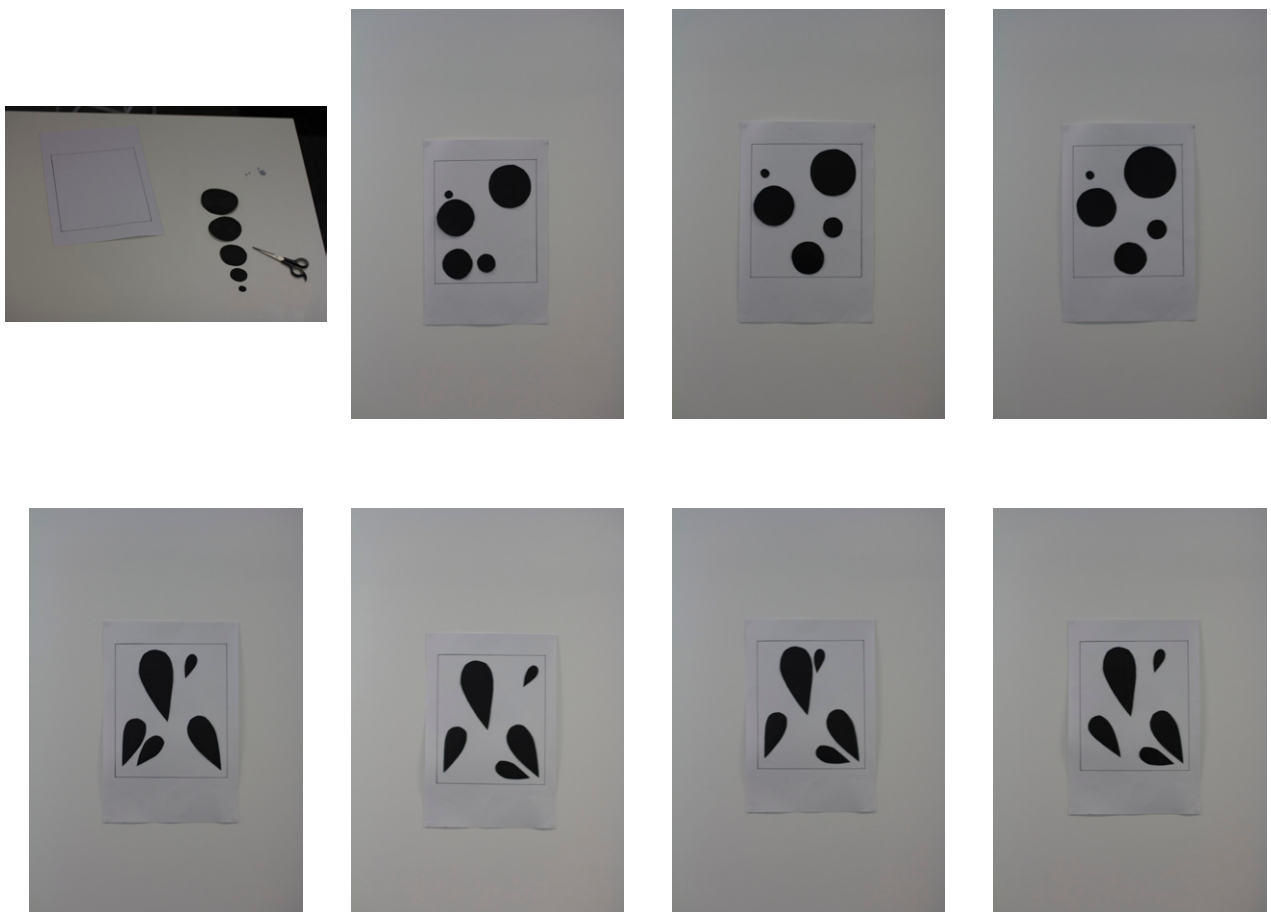


Figure 12 - 19: sequence of pictures from the three-step NOTAN exercise



## Bridget Riley and Op Art

If realized correctly, the exercise leads to an understanding of the Notan, and empower the person experiencing it with a new point of view on graphics design and on everyday life. Notan allows for a better understanding of the spaces in between. When it is discovered, the viewer experiences a “union of decoration and form .... the negative space will no longer be ‘empty’ but, instead, there will be Notan.” (Bothwell & Mayfield, 1991 pp8)

The negative space becomes an inseparable part of a whole, as highlighted by the poem at the beginning of the paragraph. This sense of discovery, of sudden realization brought upon by a design technique, lead to further studies into the field of ‘Optical art’ (Op-art<sup>5</sup>) and in particular into the work of Bridget Riley.

Most of Bridget Riley paintings are characterized by one distinct geometric pattern which repeats symmetrically over the canvas. These patterns usually are common shapes with small variation in size, or can be lines, curves which fill the surface in alternating colours, creating a composition with converging and diverging elements. Early works were mostly done using black and white paint. Later works saw the introduction of colour through the use of very specific palettes. Some examples of her work can be seen below and in the next pages.

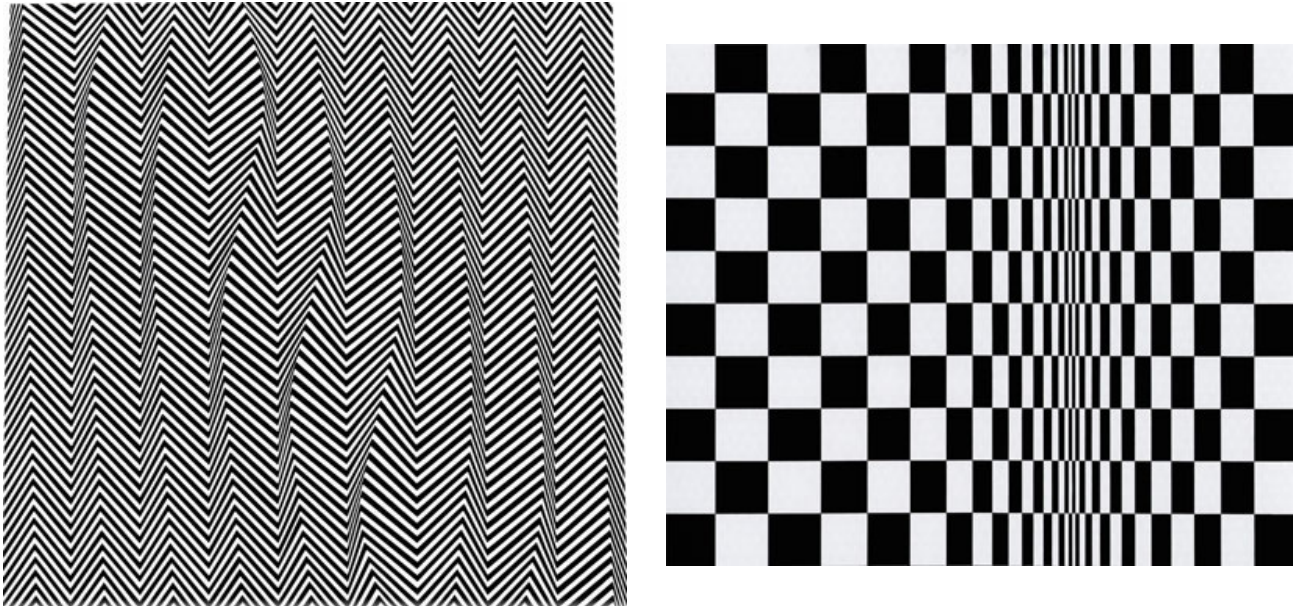


Figure 20 & 21: Works by Bridget Riley; *Descending* (1965) and *Movement in Squares* (1961), emulsion and tempera on board respectively

---

5) Optical Art can fall into the realm of Kinetic Art or not, depending on the definition of the latter. Debates on this topic are beyond the scope of this paper.

“Kinetic Art: Term applied to art that moves or appears to move. In its broadest sense the term can encompass a great deal of phenomena. Usually, however, it is applied to sculptures that are moved either by air currents or by some artificial means. In addition to works employing actual movement, there is another type of Kinetic art that produces an illusion of movement when the spectator moves relative to it (and Op-art paintings are sometimes included within the field of Kinetic art because they appear to flicker).

Op Art: “A type of abstract art that exploits certain optical phenomena to cause a work to seem to vibrate, pulsate, or flicker. The devices employed by Op artists (after-images, effects of dazzle and vibration, and so on) are often elaborations on the well-known visual illusions to be found in standard textbooks of perceptual psychology, and maximum precision is sought in the control of surfaces and edges in order to evoke an exactly prescribed retinal response. This kind of work can retain much of its effect in reproduction, but Op art also embraces constructions that depend for their effects on light and/or movement, so Op and Kinetic Art sometimes overlap.” (Chilvers, I., Osborne, H., & Farr, D. The Oxford dictionary of art).



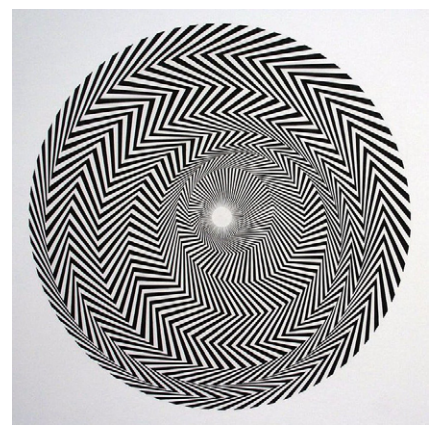
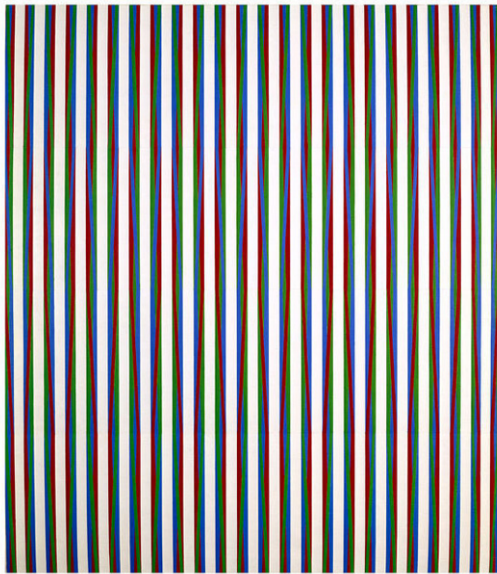
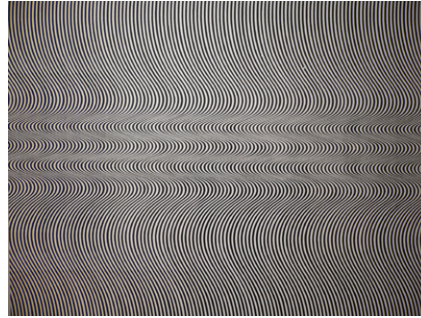


Figure 22 - 27: More examples of works by Bridget Riley. From top-left clockwise: Red With Red (2007, oil on linen, the artist herself is portraied with the painting), Current (1964 emulsion on board), Vein (1985, oil on linen), Zing01 (1971, cryla on canvas), Cataract III (1967, emulsion on canvas) and Blaze I (1962, emulsion on board).

One of the reasons why her work and that of other Op-artists reached acclaim is due to the fact that this style of painting stimulates the main motion detecting areas of the brain. This imparts to the person viewing the work the impression that the elements of the work itself are moving, even if they are still. If a person stares at the painting for long enough, or adjust their point of view accordingly, he or she can see the patterns begin to move in a repeating, wave-like fashion. The moment when the viewer realizes that the image seems to move could be compared to the moment of revelation of the Notan. Both instants lead to a discovery through visual stimulation, although in opposite ways: whereas the effect of the Notan appears as the moment of balance, of stillness, the effect of an Op-art work manifests as movement.

It is interesting to notice though that for what concerns Bridget Riley's work, the exploitation of our visual system shortcomings is not done on purpose, but rather it emerges as a collateral result of her interest in human perception from the point of view of our consciousness. "To begin with, I have never studied 'optics' and my use of mathematics is rudimentary and confined.... My work has developed on the basis of empirical analyses and syntheses, and I always believed that perception is the medium through which states of being are directly experienced." (Riley & Kudielka, 1999 pp66) A statement also confirmed by De Sausmarez: "For Bridget Riley there is no such thing as optical illusion since this would imply the censorship of visual experience by factual measurement.... for her, what is visually experienced is the optical reality." (De Sausmarez, 1970 pp16)

From this perspective, the work of Bridget Riley seems to separate itself from Op-art, which definition implies the conscious exploitation on the artist's side of certain optical phenomena and become closer to the Notan: "People at that time thought, and some people still seem to think, that they were paintings having to do with optical experiment (and with what was called 'Op art' later on); really they were an attempt to say something about stability and instability, certainties and uncertainties." (Riley & Kudielka, 1999 pp125)

This last acknowledgement elucidates how much she was/is trying to make a statement about the forces that act on people's lives, much in consonance with the concept of Yin and Yang. Just like the technique of Notan, she aims to achieve this through the wonder brought forwards by the sense of discovery that her works transmit. "I work from something rather than towards something. It is a process of discovery." (Bridget Riley quoted in De Sausmarez, 1970 pp20)

## **Moiré aesthetics**

The interest towards the moiré effect was born out of chance, when the phenomenon was first noticed on a TV screen. A musician wearing a striped long-sleeved shirt was giving an interview. The arrangement of the stripes on the shirt was obvious, however the shirt displayed additional patterns that were changing as the person moved. It was clear that those additional patterns were not part of the clothing, and theoretically were not supposed to be there. The curiosity towards the phenomenon increase throughout the years as it kept manifesting from time to time in everyday life. It was only recently, after realizing that the effect actually had a definition and it has been studied for years that the interest for it grew so strong as to lead to a formal research into it. Where do these patterns come from? Is it an optical illusion exploiting the way our visual perception works as in a work of Optical Art or is it a purely graphical phenomenon? How are these patterns created? Can they be reproduced and if so, how? What are the laws governing such a phenomenon? These are the main questions that fueled the initial approach and exploration of the moiré phenomenon.

It has been clear since the beginning that the aesthetic appeal of the moiré phenomenon was mostly due to its elusive nature. Elusive in the sense that, as explained in the session dedicated to the theoretical aspect of the moiré, even if in most cases the phenomenon is an unwanted side effect and it appears as an unpredicted artifact, it simultaneously reminds us of familiar natural phenomena, as Anoka Faruquee points out: “moirés have a fascinating, stubborn logic that parallels various phenomena in the physical world, such as wave formations, stress patterns, and magnetic fields.” (Faruquee, 2014) Another example of a natural manifestation of the moiré effect is when we observe the ripples created by throwing a stone into a body of water, such as a lake. As the waves propagate, if we throw another stone further away, the waves from the second stone will meet the ones from the first stone and create moiré.

Another interesting aesthetic perspective of the moiré phenomenon, which emerged at the early stages of the research is the idea that the moiré, like the Notan, manifests through the interaction of negative and positive, of what is there (the pattern) with what is not there (the spaces in between). Ultimately this view connects to the concept of Yin and Yang described earlier in the paper. As mentioned earlier, the initial aim of the project was to create a tool that aids in the understanding of the moiré effect. In considering how to tackle the project, a research was conducted into others' approaches to the study of the moiré phenomenon, in particular those of artists and engineers. From the theoretical side the work by Isaac Amidror proved to be the most complete and the most useful, as demonstrated in the dedicated section. From an artistic perspective, throughout the years many artists used moiré in their works. For the sake of conciseness we would consider only artists whose works deliberately and consciously use the moiré phenomenon.

## **Relevant approaches to the study of moiré**

Among these, Liz Deschenes uses camera film to create the moiré effect, either via film sandwich or through double exposure of the negative, which are later printed on a large scale. As a source for her most recent works, she used a sheet of perforated paper against a bright open window. Two exposures were recorded and the two negatives were then superimposed slightly off-kilter and printed from an enlarger. As mentioned from the description of her work *Moiré #25* (2009, see figure below) part of the permanent collection of the MOMA since 2013, this work demonstrates her engagement with “the relationships between abstraction and representation and the uniquely handmade and the mechanically reproducible.”

Faruquee also explores the moiré effect in her most recent paintings. She describes her approach to moiré in her artist's statement on her website: “my recent paintings explore this interference effect: I overlay two or more offset patterns and the fusion creates another pattern that is quite unlike and much more complex than any of the individual ones. At the heart of the moiré phenomenon is the gulf between what is described (circle on circle, for instance) and what is ultimately experienced. But for me, the phenomenon not only exemplifies the plasticity of perception, but also models the dynamism of the physical world.” (Faruquee, 2014)





Figure 28: Anoka Faruqee *P-30* (2012, Acrylic on canvas)



Figure 29: Anoka Faruqee *P-49* (2012, Acrylic on canvas)

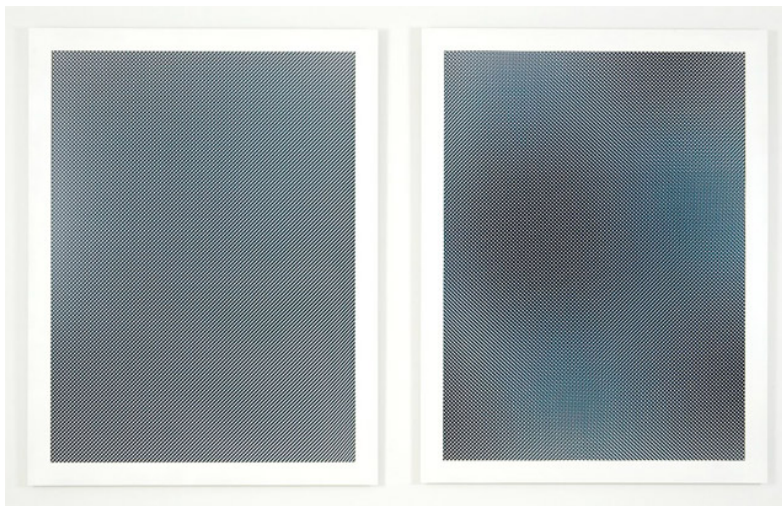


Figure 30: Liz Deschenes *Moiré #6* *Moiré #7* (both 2007, UV laminated C-Print)

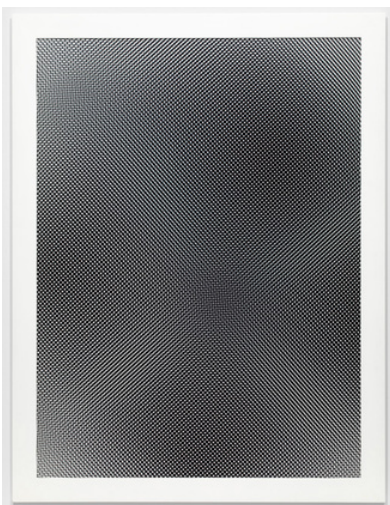


Figure 31: Liz Deschenes *Moiré #25* (2009, UV laminated C-Print)



Other artists and works that are worth mentioned are Linda Basemer's Swoop Wave Bulge series (2013), many of James Cousins' paintings, in particular pl.518 (2013) and the rest of works from the series New Work'13 (2013). Edward Ruscha's Pure Ecstasy (1974). Reginald Neal's Red Circle (1965) and Red Moiré On Blue (1964) and Richard Anuszkiewicz's Deep Magenta Square (1978).

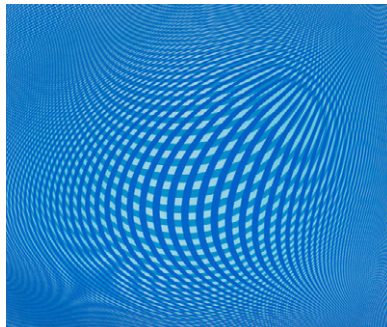


Figure 32: Linda Basemer, *Swoop-WaveBulge 1 x (blue)* (Acrylic on canvas)

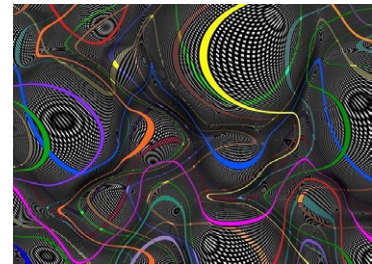


Figure 33: Linda Basemer, *Swoop-WaveBulge#2* (Acrylic on canvas)

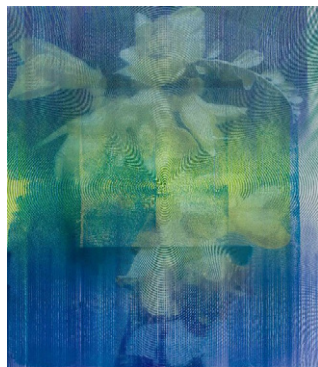


Figure 34: James Cousins, *pl. 58*, (oil and acrylic on canvas)

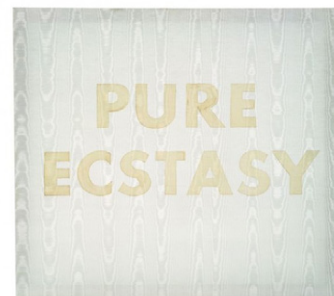


Figure 35: Edward Ruscha, *Pure Ecstasy*, (shellac on moiré rayon)

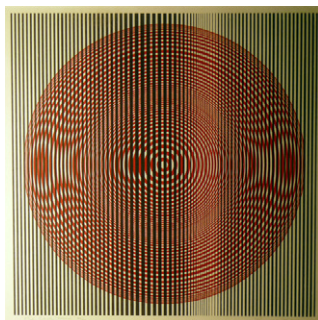


Figure 36: Reginald Neal, *Red Circle*, (Lithograph)

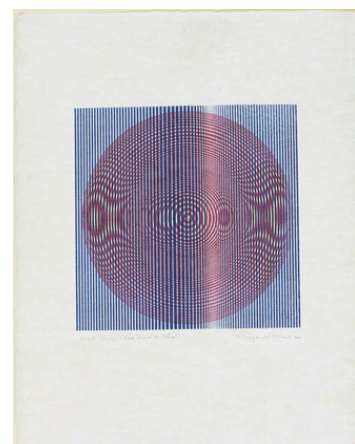


Figure 37: Reginald Neal, *Red Moiré on Blue*, (Lithograph)

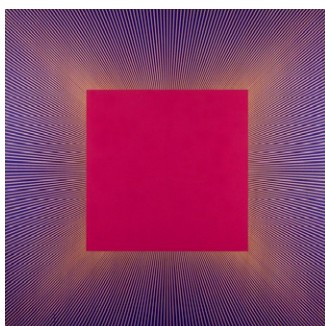


Figure 38: Richard Anuszkiewicz, *Deep Magenta Square* (acrylic on panel)

## Moiré Index

Above all, the work that influence the realization of this project the most, beside the research of Isaac Amidror, is the work of artist Carsten Nicolai in his book *Moiré Index* (2010, see reference). The work of Carsten Nicolai is mostly characterized by the exploration of scientific phenomena and one of his recent work is the publication of *Moiré Index*. In this book, Nicolai explores the moiré effect through the publication of individual graphic files that can be used to create almost endless amount of new overlays.

From the publisher website: “*Moiré Index* is the definitive reference book for designers, visual artists, architects, researchers, mathematicians, or anyone else who wants to use its content as a basis for graphic designs. A CD accompanies the book and contains the featured moirés as digital files.” ([://shop.gestalten.com/moire-index.html](http://shop.gestalten.com/moire-index.html))

*Moiré Index* is based upon years of research, and is meant to be a practical tool for anyone exploring the moiré effect creatively. Nicolai analyzed and unlocked these structures and created a fundamental framework of the subject. Unlike Amidror, Nicolai employs an algebraic approach to the study and explanation of moiré, but still recognizing the importance of Amidror’s book for his own work: “moiré index owes a great deal to the research of Isaac Amidror” (Carsten, 2010 preface) The main reason why Nicolai and this specific work of his are a strong influence on this project is because many patterns files from the book are used in the application, together with some moiré file from Amidror’s book. Other approaches to the generation of patterns for the recreation of the moiré effect had been unsuccessfully tried before reverting to the use of pre-made patterns.

## Moiré and movement

It is extremely interesting to notice how the moiré effect manifest as an integrated part of the overall visuals. Let us say that an observer is trying to distinctively distinguish each layer of a painting or a printed image that manifests the moiré effect. In most cases it will take a certain amount of time and effort to successfully accomplish the task and isolate the layers. Sometimes the pattern would appear so complex that it would be too difficult to separate the moiré from the original layers. This shows that it is more complicated to discern and understand the moiré effect by itself without knowledge of how the original layers look like. This aspect of the phenomenon is partly due to the fact that the moiré effect appearing in a picture, painting or other form of printed works is static. Alternatively, a dynamic representation of the moiré, where one layer would be static and the other/s would move, would greatly aid in the understanding of the phenomenon. With movement it would be simpler for the same observer to distinguish the single layers and it would also be much easier to distinguish the moiré. The visuals will fluctuate from a state of no-moiré to a state where the effect is fully manifested, displaying in between all the various moirés associated with that particular combination of images, further emphasizing the connection of moiré to the Notan. Carsten Nicolai shares this concern about an approach to the study and understanding of the moiré phenomenon through the aid of dynamic patterns: “... although moiré index hints at the infinite potential of how to produce moirés, the example given here can only deal with static two-dimensional interference patterns. To more effectively reach into the subject it is essential to examine the phenomenon with moving patterns.” (Carsten, N., 2010 preface)

Following this reasoning, it was decided to create a work that would incorporate a dynamic aspect into it. This translated into the ability to rotate and shift up and down one or more layers, allowing for a more comprehensive approach to understanding the moiré effect. Some online resources (see Weisstein and Gabrielyan for examples) do demonstrate the moiré effect with the use of moving patterns, however they are in the form of automated repetitive GIFs. After the initial novelty phase, in which a visitor of the website get acquainted with this new way of demonstrating the moiré effect, the lack of interactivity can soon make the demonstrations slightly mechanic, bland and less engaging. It was therefore only natural to incorporate interactivity into the project.

The ability to be able to control the generation of the moiré to a certain degree could also aid in making the person interacting more curious about what is behind this effect, pushing them to learn more in depth about the science behind the moiré phenomenon. Some scientific software languages, such as Matlab, Mathematica or Sage<sup>6</sup> for example, do offer the possibility of creating an application capable of displaying the moiré effect, however, Processing<sup>7</sup> was chosen as the software to use mainly due to its popularity and portability. To the best of the author's knowledge, currently there is no existing Processing application that has been created specifically for the study of the moiré effect, and this has provided its pro and cons.

## **Moiré and sound**

Adding moving patterns and interactivity however was not enough. It was decided to add a sonic component to the project. This decision raised the question of what would be a suitable approach, of what sound sources would fit the project. "I appreciate the moiré effect because it challenges optical perception.... its counterpart in the audio field – sonic effects caused by phasing and superimposition of frequencies – has also been a valuable tool for me to explore sound production." (Carsten, N., 2010 preface) As Carsten Nicolai suggests, the overlapping of frequencies is by intuition the audio correspondence of the visual moiré effect, but this concept needs some clarification. Technically every single sound with the exception of pure tones is a superimposition of frequencies, as discovered by Fourier. Even acoustic reverberation is a form of sonic moiré. However, what Nicolai seems to refer to in that statement are sounds generated by the combination of a limited number of different sine waves with modulating frequency, phase and amplitude. It was thus decided to start the exploration of sound in connection to moiré from the simplest sonic moiré phenomenon: monaural beatings. Refer to page eight for more information about monaural beatings.

In researching composers and musicians whose works consciously explore the moiré phenomenon, it was decided to focus on those that made beatings an important feature in their works. Even with this restriction the number of artists/musicians/composers devoted to the exploration of beatings is quite vast. Most of these artists arrive to the use of beatings from a microtonal approach and include composers like Giacinto Scelsi and all the Spectralists (in particular Gérard Grisey and Tristan Murail). Also selected works by Iannis Xenakis, such as *Metastaseis* (1953-4) and *Pithoprakta* (1955-6) and some of Terry Riley's and La Monte Young's works contain good examples of musical beatings. Certain oeuvres by Robert Ashley, Gordon Mumma and Tony Conrad also contain representations of this effect, together with Phill Niblock's *Stosspeng*, *Poure* and *One Large Rose* (all circa 2009), amongst other of his works. Many Japanese artists using no-input mixing desks also exploit beatings, notably Otomo Yoshihide, Toshimaru Nakamura and Sachiko M. Traditional music such as Indonesian Gamelan where beatings are an embedded part of their structure is worth mentioning. Additionally, contemporary composers Glenn Branca and Rhys Chatham and rock band Earth, in particular their album *Hex*; or *Printing in the Infernal Method*, (2005) deserve to be mentioned, as in many of their works beats are a prominent feature.

---

6) These software are defined as computer algebra systems and allow for the study of mathematical phenomena and theory. Some offer the possibility to graph and display the results of the equations and formulas that are typed into the program.

7) Open source software specifically designed for artists.



However, none of the above mentioned artists have researched into the phenomenon of beatings as in depth as experimental music composer Alvin Lucier, whose work is influenced by acoustic phenomena such as feedback, phasing and beatings amongst other. He explored monaural beats through non-conventional means, sometimes via the use of uncommon instruments like the bagpipe (with the addition of live electronics) as in *Piper* (2000), or with the use of the traditional music instrument like the Japanese Koto, as in the piece *Fan* (2003, also with live electronics). Other times he ventures into the realm of monaural beats via the utilization of purest tones, like in *Ever Present* (2002), for flute, piano, alto saxophone and live electronics and *947* (2001), for solo flute and tape. He even experimented with beatings via a piece written only for the triangle: *Silver Streetcar For the Orchestra* (1998). A composition that deserves a separate paragraph is *Canon* (1996). In this piece for clarinet, vibraphone, piano, cello, electric guitar and double bass, Alvin Lucier beautifully exemplifies the phenomenon of monaural beats. A sweeping wave created by the three stringed instruments is the sonic foundation for the rest of the ensemble to lay their parts over. The vibraphone, piano and clarinet play single tones at very specific times, thus creating audible beats that slow down and speed up as the fundamental pitch of the sweeping drone is closer or further away from the tones. These particular approach allows for the creation of rhythmic material that is the result of the different beats interacting with each other at different rates.

Figure 39: Alvin Lucier, scan extract from the score for *Canon* (<http://materialpresscom/lucier.htm>)



## Brief overview of examples for sound and visual interaction

Part of the research has been briefly dedicated to gaining basic knowledge into some of the different approaches to audio and visual interaction, with particular emphasis on artists with a minimalistic approach to the subject and that exploit systems glitches in some form or another. Amongst them, Phillip Stearns offer an interesting view on the use of visual (in this case referred to as light) and of sound: “Light and Sound themselves become raw materials for reconstituting electronic signals back into physiological experience” (Stearns 2014). Other artists of which work has been considered for this project include Tina Frank, Tavid Toop, Robin Fox, Lenn Lye, Bot Borg and the design style of label Raster-Noton and its associated artists, such as SND and Ryoji Ikeda.

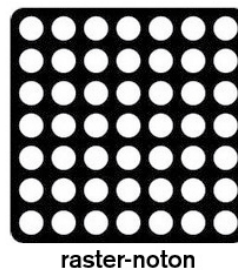


Figure 40: Raster-Noton logo (<http://www.raster-noton>)

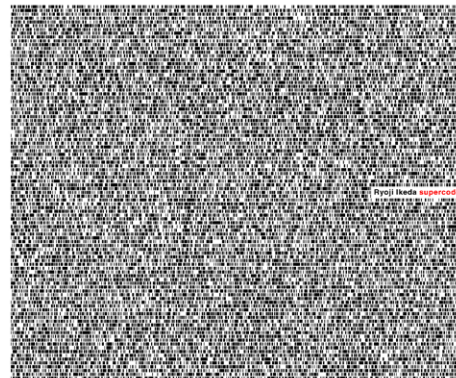


Figure 41: Ryoji Ikeda album cover for *Supercodex* (2013 , <http://www.raster-noton.net/> )

The present state of the work itself is in the form of a Java applets (more next page). Once the application is running, the graphics are displayed as a medium-sized window in the middle of the screen. The person interacting has control of the angle of rotation and vertical position of one layer, via mouse/trackpad interaction and via UP and DOWN keyboard arrows respectively. The sound is presented via headphones and is also controlled by the mouse/trackpad movement. Please see images below.

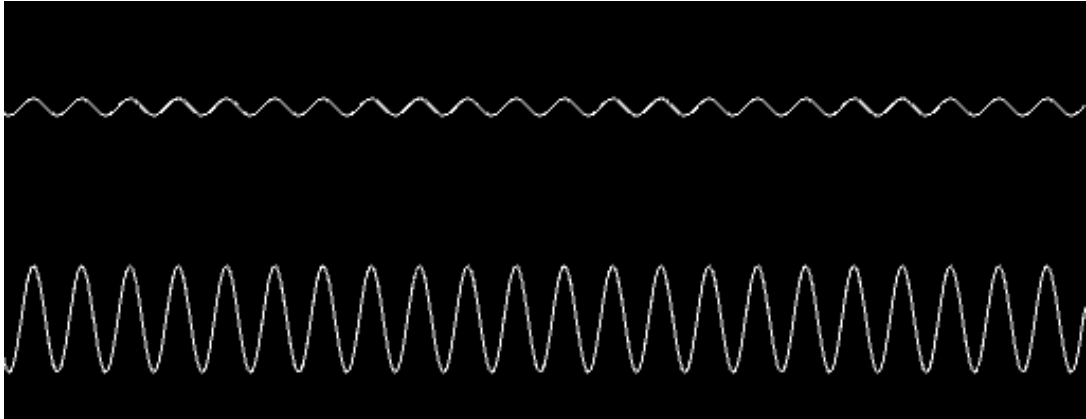


Figure 42: Screen shot of application used during research stage for the sonic part of the project.

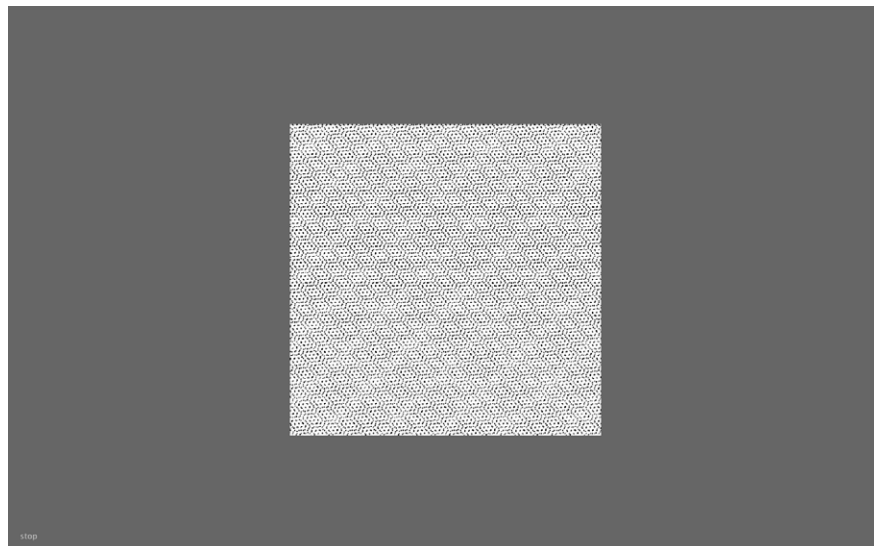


Figure 43: Screen shot of full-screen display of the interactive application at its current state as a Java Applet.

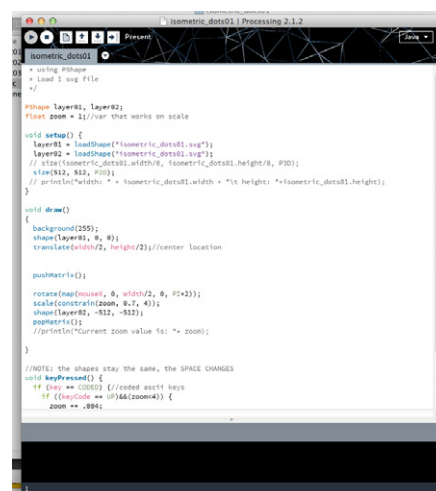


Figure 44: Screen shot of part of the Processing code used for the application.

## Conclusion

Currently the project is still in its embryonic state and is presented as a working prototype. As only one person is developing this project, progress is slow. To be available to the public, this project still requires many improvements and adjustments.

## Presentation

For what concerns the presentation of the project a graphical interface needs to be added. This will be in the form of either an on/off 'drop down' menu or it will be permanently displayed on one side of the area covered by the graphics. It could also be the combination of the two (a 'drop down' menu outside of the main area). The menu, once displayed, will include a brief set of instructions highlighting the main controls.

It will also incorporate a drop down menu for each layer allowing the person interacting the ability to choose which pattern to use in various combinations, with an additional option for having the layer empty. This last option will make it possible to display just one layer at the time thus allowing the users to recognize what patterns are used for each layer and will aid to a better understanding of their interaction and resulting moiré.

At present the project includes a variety of shapes, grids and dot-screens that can be used to provide examples of the moiré effect over a two-layer setting. Some are producing interesting results only at very specific positions and settings. For this reason the reduction of the number of patterns to choose from is under consideration. The addition of a third layer might also increase the number of interesting moirés as seen in some examples from Amidror's book, although this option is to be tested. At this point it is worth pointing out that the display screen itself, as it is a grid of pixels, acts as an additional layer, and in some cases does influence the resulting moiré. For this reason it was decided to use SVG<sup>8</sup> file format as opposed to PNG (other graphic/picture file-types do not allow to export transparency). If PNG files are used, the computer screen resolution would influence the way that the file is displayed, adding unwanted effects and in some cases making the graphics look very pixelated. SVG file format is resolution independent and therefore the screen resolution would have a far less impact on the graphic. The implementation of SVG also allows for a greater portability for the project, as it would look the same in different screens, including portable devices. Unfortunately, the way that Processing implements the SVG format is only partial. Because of this it took a lot of work and experimentation to get the pattern files to work in the desired way in Processing. Another positive feature in using SVG instead of standard image files is that, if the project is implemented online as we will discuss later, SVG contributes to a quicker loading time of the webpage. Furthermore, the ability to make the graphical appearance of the project to be the same throughout different devices' displays can be useful if in the future it will be decided to adapt the interactive features of the project for touch screen devices, although this idea might be implemented only towards the end of the project.

The next feature to implement in the project after the addition of a menu will be its actual deployment online. As mentioned earlier, the current state of the project is in the form of a Java applet. A Java applet is an application created in Java that can run online independently of the browser used and also on a computer for testing purposes. Besides being operating system-dependent, thus making the portability of the project extremely complex, "few web developers deploy Java-based web applications now" (<http://processingjs.org/articles/p5QuickStart.html>). This format is slowly being deprecated and replaced by other web technologies such as the canvas attribute in HTML5. Therefore a Java applet is limited to run directly on the device and even though it can be embedded into a web page, an option still available in Processing, is not a feasible choice for this project. Another option incorporated into Processing IDE<sup>9</sup> is to export the program as a webpage itself. This is the best solution but requires some knowledge of JavaScript and of HTML, knowledge that is being gained at present. The possibility to include the option to export a screenshot of the moiré as a PDF or JPG file is also under consideration.

---

8) SVG stands for Scalable Vector Graphics

9) IDE: Integrated Development Environment; a software application that provides computer programmers all the necessary tools for software development in one package.

## Approach to sound

In addition to the work that has to be done on the presentation format, at the moment the main issue that concern the project is a technical one. The way the sound is created and modulated depends on the mouse position in respect to the area occupied by the graphics. Sound and visual are controlled by the same interface but are generated independently. The ideal set up for the project would be to have the visual driving the sound. If done properly, this will further increase the connection between the visual moiré and the audio moiré, thus highlighting the idea that both medium are representing the manifestation of the same effect. At present, the main problem with the sound is that it is only using monaural beats as sound synthesis technique. As mentioned earlier, this is a very specific case of audio moiré and does not fit all the combinations of moirés that the visuals can demonstrate. For the sonic equivalent of the visuals moiré to be truthful, FFT analysis has to be implemented into the program code. This will create a scientific connection between the two forms of moiré, and the sound will be a true representation of the visual.

According to Amidror, the “spectrum of the superimposition (the moiré) of two cosinusoidal is the Fourier transform of their product”. (Amidror, 2009 pp16) Theoretically, by applying a real-time Fourier transform to the image, we would obtain the representation of the picture in the frequency domain in the form of isolated frequencies as in a standard spectrograms. We could then use that information to control the creation of the sound, most likely via additive synthesis. This approach has been further discussed with an engineering professor at AUT, who agreed upon this methodology and added some suggestions, for example the implementation of a 1D transform instead of a 2D transform. This new development in the research requires a deeper mathematical knowledge. This will further extend the completion date of the project, but it is a necessary step. A mathematical and therefore theoretical understanding of the moiré phenomenon and of FFT analysis is needed to fully gain a correct insight of the model and of the technique. A work with a better foundation in the mathematical and theoretical aspects of the moiré effect will also help to withstand comparison with existing works such as that of Nicolai. Closer collaboration with an engineer or mathematician would also speed up the process exponentially. A geometrical approach has also be considered, however it is not as useful as FFT analysis in determining the right parameters for the generation of the sound.

## More than meet the eyes and ears

It is interesting to notice how a phenomenon like the moiré, which seems simple on the surface, needs a complex mathematical model to be fully described. Another connection to the duality of the Yin and Yang, in this case as a phenomenon that is both simple and complex at the same time. As Matt Pearson points out: “Order and chaos, simplicity and complexity, the mechanical and the organic, aren’t necessarily at opposite ends of a spectrum. They’re symbiotic, intertwined. Any line we might walk between the two is a knife edge. Our very existence is poised between entropy and order, between the turbulence of a hostile, chaotic environment, the natural world that we would find so difficult to survive unaided, and the simplicity of purest nothingness, the void that is equally fatal to our animal needs.” (Pearson, 2011 pp xxviii)

This is probably why the complex appeals to us as much as the simple, and why the manifestation of moiré patterns attracts the interest of so many artists that instead of rejecting such artifact as in other professional fields work with it, embracing its nuances and aesthetic. Much like the notion of the Yin and Yang, simple and complex, wanted and unwanted, interconnect like any other opposition found in life. This project set out as an attempt to be create a context in which to connect to these visual energies “to unlock their true potential and latent characteristics.” (Riley, B., Kudielka, R., 1999 pp88), in hope to induce the person interacting with it to a new awareness of what before was considered to have no particular meaning or was treated as a nuisance. Creating a new unity, just like the design technique of Notan, to improve one’s attention to the spaces in between.

## References

Moore, Brian C. J. (2012). An introduction to the psychology of hearing, 6th ed. Emerald Group Publishing Ltd

Bergeijk, W. A. v. (1961). Waves and the ear. London: Heinemann.

Johnston, I. (2002). Measured Tones: The Interplay of Physics and Music. Bristol and Philadelphia: Institute of Physics Publishing.

Tartini, G. (1754). Trattato di Musica Secondo la Vera Scienza dell'Armonia. Padova: Giovanni Manfrè

Wolfe, J. (2011) Tartini tones and remperament: an introduction for musicians. <http://www.phys.unsw.edu.au/jw/tartini-temperament.html>

Bothwell, D., Mayfield, M. (1991). Notan: The dark-light principle of design. New York: Dover Publications.

De Sausmarez, M. (1970). Bridget riley. London: Studio Vista.

Riley, B., Kudielka, R., De Montfort University, & Serpentine Gallery. (1999). The eye's mind: Collected writings 1965-1999. London: Thames & Hudson in association with the Serpentine Gallery and De Montfort University.

Chilvers, I., Osborne, H., & Farr, D. (1988). The oxford dictionary of art. Oxford: Oxford University Press.

Nicolai, C. (2010). moiré index. Berlin: Die Gestalten Verlag GmbH & Co.

Nicolai, C., Strauss, D., Doswald, C., & Haus Konstruktiv (2007). Carsten Nicolai: Static fades. Zürich: JRP/Ringier.

Amidor, I. (2009). The Theory of the Moiré Phenomenon: Volume I: Periodic Layers. New York City: Springer

Amidor, I. (2010). Selected highlights from the moiré demonstration kit. <http://lspwww.epfl.ch/books/moire/kithl.html>

Pearson, M. (2011). Generative Art: a practical guide using Processing. Shelter Island, NY: Manning Publications Company.

Lucier, A. (1996) *Canon* musical score  
Frankfurt: Material Press  
<http://materialpress.com/lucier.htm>

Online; all links current as of 06 April 2014

The office of learning and teaching, Sydney school of Physics.  
Interference beats and Tartini tones.  
<http://www.animations.physics.unsw.edu.au/jw/beats.htm>

Gabrielyan, E. The basics of line moiré patterns and optical speedup.  
<http://switzernet.com/people/emin-gabrielyan/070306-optical-speedup/>

Gabrielyan, E. Aperiodic random line moiré.  
<http://switzernet.com/people/emin-gabrielyan/070227-random-line-moire/>

Gabrielyan, E. Shape moiré patterns.  
<http://switzernet.com/people/emin-gabrielyan/070320-shape-moire/>

Morse, S. et al (1961). Geometry of moiré fringes in strain analysis.  
<http://4z.com/people/emin-gabrielyan/public/070227-moire-ref/Morse61a.pdf>

Nishijima, Y. Oster, G. (1964). Moiré patterns: their application to refractive index and refractive index gradient measurement.  
<http://4z.com/people/emin-gabrielyan/public/070227-moire-ref/Nishijima64a.pdf>

Weisstein, Eric W., Moiré Pattern. MathWorld A Wolfram Web Resource.  
<http://mathworld.wolfram.com/MoirePattern.html>

Steven, L. An Intuitive Explanation of Fourier Theory.  
<http://cns-alumni.bu.edu/~slehar/fourier/fourier.html>

Weinhaus, F. (2000). ImageMagick v6 Examples – Fourier Transforms.  
<http://www.imagemagick.org/Usage/fourier/>

Clinton Watkins  
<http://www.circuit.org.nz/film/force-fields>  
<http://www.circuit.org.nz/film/landscape-distortions>  
<http://eyecontactsite.com/2013/08/clinton-watkins-installation>

Anoka Faruquee  
<http://anokafaruquee.com/>  
<http://anokafaruquee.com/artists-statement>

Linda Basemer  
[http://www.anglesgallery.com/ssp\\_director/artistgallery.php?id=7](http://www.anglesgallery.com/ssp_director/artistgallery.php?id=7)

Phillip Stearns  
<http://phillipstearns.wordpress.com>

James Cousins  
<http://www.gowlangsfordgallery.co.nz/artists/jamescousins/>

Edward Ruscha  
[http://www.moma.org/collection/object.php?object\\_id=84191](http://www.moma.org/collection/object.php?object_id=84191)

Reginald Neal  
[http://www.moma.org/collection/object.php?object\\_id=60648](http://www.moma.org/collection/object.php?object_id=60648)

Liz Deschenes  
[http://www.moma.org/collection/object.php?object\\_id=159172](http://www.moma.org/collection/object.php?object_id=159172)

Richard Anuszkiewicz  
<http://www.richardanuszkiewicz.com/>

Raster Noto  
<http://www.raster-noton.net/>

Processing  
<http://processing.org/>  
<http://processingjs.org/articles/p5QuickStart.html>  
<http://forum.processing.org/two/>