

The Puzzle Factory's, Generative Art Studio

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Abstract

I would like to take the opportunity to describe some of the objectives and practices developed at The Puzzle Factory in the hope that we may find collaborators with similar motivations and different skills. I am in the process of trying to materialise a project I have spent my life researching: how to create a long lasting art collective. My hypothesis is that the principles of generative art are ideal for fostering collaboration between different practitioners, especially when they may be operating remotely. Most of my career has been spent working on my own but by being conscious of performing different roles, I am able to develop and test different processes, protocols and presentations.

My experiences and skills cover a variety of fields though I am aware of where my

particular talents lie and more importantly where they lack. My strengths are in producing artwork and in this paper I try to explain some of the systems I have set up and the technical solutions I have tried in response to restrictions self imposed or otherwise.

Introduction

My long term area of study within art has been the ideal artist collective/network. This topic is how I became interested in Mathematics to begin with. The Puzzle Factory is my studio where I am implementing my findings with the aid of a small network of creatively, technically, and scientifically gifted individuals. The ideal creative network .3z/ requires a diversity of knowledge and skills as well as good management, people skills and structure. Lacking the latter three of these, most of the time my creative network is just me wearing different hats. The objective of The Puzzle Factory is to create a beautiful world built on art and mathematics. The strategy behind this is to share knowledge within a productive community both scientific and creative, raise the profile of mathematically minded art in Britain, find applications for mathematical art, commission work and make the world a little more amazing. It is a policy of The Puzzle Factory to use 'she' as the default pronoun regardless of sex.

Aspects of an artwork

A painting, like most forms of art, exists in multiple forms of space. The material aspect exists in physical space, this is made of the layers of ground, paint, varnish, pigments that the creator puts together to make the painting. The compositional aspect is a visual structure, existing in the space created by the artwork, depicted by the creator that may be recognised from a real or abstract world. For example the painting could be of a landscape, figure, shape, concept and so on. Thirdly an intangible aspect detectable in the way these two aspects meet. The intangible aspect contains the energy and emotions of how the work was executed, what the artwork is expressing rather than depicting, it is the artist's hallmark and mystery. An artist should be able to describe compositional and material aspects, the reasons that determined choices made in them. However it is the work itself that is describing the intangible aspect and that is for the viewer to interpret in their own manner. In this way an artwork is often performing different actions simultaneously. Just because a painting is of one thing, that doesn't mean it isn't also about or because of something else whether or not the creator is conscious of what that is.

Collaboration in Art

Painting is considered to be typically a solo enterprise, with few protocols in place to facilitate collaboration. Music on the other hand involves a great deal of collaboration and over time solid frameworks have been put in place to allow various artists to work together efficiently. Put into the terms defined above, the material aspect of a piece of music being the sounds from chosen

instruments, the compositional aspect determined by the composer and described in the form of a score, then the piece is performed by the individual musicians under the discipline of the conductor. In this manner a conductor can collaborate directly or across time with the composer, interpreting, arranging and expressing the original composition with their own specific intangible aspect. The power that a well disciplined orchestra can have with a composition it identifies with can be overwhelming. It has to be very much a collaborative effort, as the material aspect itself is made of individuals with their own opinions and enthusiasm. If the orchestra does not stay current with its repertoire it can become irrelevant and few contemporary composers write with an orchestra in mind. To combat this we have an additional understated role in the form of an arranger. An arranger can take a composition and adapt it for a specific ensemble. In Manchester we now have a new generation of audiences listening to electronic, dance and post punk classics performed by live orchestra in innovative locations.

Frameworks for collaboration amongst painters are typically determined by necessity for purposes of scale and time constraints. Collaboration requires relinquishing some control. Most painters are unknowingly collaborating with others at the material level by choosing to buy paints made by a manufacturer, a task previously performed in the studio. They may collaborate at a compositional level with architects by painting their buildings, fashion designers with clothing on a model, writers with illustrations. A lead artist may enlist the help of others and guide them with the use of projections

and gridded up images but keep a strict control on how the work is carried out so that they maintain the intangible aspect. Artists such as Jeff Koons have taken this distance a step further in the postmodern age by removing themselves completely from the production of the artwork. This approach reflects the late twentieth century's reverence for the uniformity of the disposable product.

Wings of the Art Collective Spectrum

During my time studying and working with artistic collectives I have come across bespoke methods for facilitating collaboration or direction determined by each groups circumstances and motivations. As with all approaches to working with people, the collective faces trade-offs at every turn. The most autonomous collectives are basically studio co-operatives, where each member has a space where they produce their own work. In these cases the collective power is in the production of a diversity of work. The individuals benefit from a workspace and creative freedom, but lack of cohesion creates difficulties with presentation, marketing and selling. Collectives like this often try to open a gallery, but as they are chiefly built up of minds geared towards production and creativity they find open studios better. An open studio event is where the artists are encouraged to present their own work in their own space, they can collectively benefit from their diverse social networks, but being tricky to organise, may only happen once a year. At the opposite pole is the autocratic collective, where one artist takes creative control. Others produce the lead artist's work with a level of management and administration

between. Individuals benefit from an income, the lead artist bares the risk, but also has all the glory and creative freedom. The autocrat's employment of good management results in a consistent output of artwork that is high in quantity but low in diversity which in turn is easy to market. This type of collective is sold as an individual artist and can gain clout over galleries. As you may expect the biggest trade-off between these two extremes is the intangible aspect of the artwork: the autonomous collective producing distinct works with the hallmarks and faults of the individual, the autocratic churning out works indistinct from those made by machine, perfect, but soulless.

Protocols at the generative art studio

"Generative art refers to any art practice in which the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, that is set into motion with some degree of autonomy, thereby contributing to or resulting in a completed work of art."

[1]

Generative art principles lend themselves exceptionally well for creating artwork in a largely autonomous collective. A traditional art studio may have a lead artist who designs how a finished artwork will look and then have assistants to realise that vision. A generative art studio could function by taking the convention in music where a composer may write a score, which is then interpreted by a conductor, who then directs an orchestra to perform the piece. A generative art studio could have an originating artist

(the composer or composers) who designs the system or the rules for how an artwork is produced. The production of the piece is then determined by how those rules are put in place by a conductor and the conditions in which they are executed by the executor. I should clarify here that humans are optional, sometimes a conductor is a tool or a program, an executor could be a machine, and even the composer could be an artificial intelligence, or arbitrary rule generator. Of course they could be combinations.

Among the benefits of working as an individual is being able to just get on with the project. As soon as others are involved, ideas have to be articulated and questioned. It is important that conventions are met in order for contributors to be replaceable and some organisations may be overly in love with meetings. This can be beneficial and informative or a time consuming hindrance. A generative art studio is not a software company and the methods and needs of the artists must be respected or they will die of bureaucracy poisoning. The Puzzle Factory consists mainly of talented introverts who can easily spend hours in discussion and sharing knowledge but generally prefer getting work completed rather than talk about it. We have a basic system in place for working on projects remotely and do not need to communicate all the time.

In the folktale of the girl with the seven swans (or ravens) the protagonist has to be silent for six years while she completes her task. Lewis Hyde uses this to convey the importance of not even trying to communicate during the creative process.

A project will typically have a lengthy

gestation period, during that time it gathers form from ideas and experiences but it does so mostly in the composer's head, across various note books. Every decision and possibility gets scrutinised, weighed and justified or discarded, not necessarily in silence but certainly in private. Once a decision is made, the justification is shelved and the actual decision is what must be remembered for the execution of the project.

After the gestation period, the project has reached the point where it is ready to be realised. Traditionally the lead artist, designer, or the art director has to communicate her vision to a team, defend her decisions and ensure everyone understands what the final outcome will be. In a generative art studio, however, the composer presents a system that determines the compositional aspect of the artwork. The system provides a structure which accounts for the variables in the material aspect and is articulated through a conductor to the executor. Decisions have been made, the composer relinquishes control, what happens next and the final outcome can only be estimated or visualised by models the composer may have made.

Once a project has been realised and submitted for presentation, there is no reason it could not be taken up again and interpreted in a different material requiring a different conductor, or the rules adapted by the same or different composer, or even just repeated with the same controllable variables.

The projects I have composed, conducted, or executed for the puzzle factory have taken inspiration from mathematics and forced me to make tools that have then been used for other projects.



Truchet Tiles

Truchet tiles found their way into the Puzzle Factory lexicon originally as a solution to a problem around right angled quadrilaterals. They were named after the French priest Sébastien Truchet [2]. The potential for their application quickly overshadowed the original project and with some adaptations have since become the face of The Puzzle Factory. The individual truchet tile does not have rotational symmetry: a single square tile can be placed in 4 different configurations on a grid. A rosette of two tiles has 16, a rosette of three has 64, a rosette of 4 tiles has 254.

As well as being an attractive square these tiles can create a numerical system in base 4. With a 2 by 2 square arrangement of 4 tiles having 254 different configurations. The rosette of tiles offers possibilities for creating pattern forming encryptions.

I systematically enumerated each combination in such a rosette, then picked the most distinctive arrangements that had aesthetic appeal based on symmetry from each group of eight rosettes.

A letter represented by a rosette can be deciphered according to the rotations of its component tiles, providing the original order of rotations is known. Bottom right

determines which quadrant of the alphabet (the final quadrant consisting of just Y and Z), bottom left determines which quadrant of that quadrant, now there are only two possibilities indicated by the top right which has two options per letter. The top left tile tells you nothing, but because of the symmetry involved, could change the letter completely if the tile were upside down. I now had a fun project for some suitable executors: children while their school was closed during the pandemic. I needed a conductor that would make the bridge between the executors and the material aspect (a wall and acrylic paint), while ensuring the rules were maintained. Quite simply I made large square stamps for each letter they needed using sponges. The executors stamped their names onto the building creating patterns unique to them. There was no rule that said exactly how the rosettes of rosettes should line up, nor what colours to be used, or consistency of paint.

I decided that the designs I was getting lacked a certain elegance, and I may also need an upper and lower case alphabet. By simply changing the straight diagonal line to a curve, I suddenly had two more versions of the alphabet. One for upper case, one for lower and the original for numerals and punctuation. I exported the design as a font file which becomes a conductor for the computer screen acting as executor. A more interesting outcome would require a few more conditions and a little more sophistication in the conductor. I wrote a simple program which would take a 16 character string, arrange them into a square, randomly assign them an upper or lower case, display them in this Truchet font and suddenly I had the logo

for The Puzzle Factory that could constantly redesign itself with 16! different results.

Playing around with this a little further lead to more projects. Some of them simple interactive puzzles I refrain from describing in case I reveal the solutions. The most ambitious project involved a material aspect I had wanted to explore for a long time. It began with a few minutes on a word processor and ended with an antique looking new kitchen floor. The material aspect required building new tools, researching and trying various recipes, many failures, experiments and much mess before I could perfect the technique. I had my dream kitchen floor made from hand made cement truchet tiles. It doesn't spell anything but from previous information an observer should be able to narrow down what those letters may be.



Interception game

An early project from the Puzzle Factory that uses language, encryption and an unusual base numerical system began with the expectation that the material aspect would be a musical piece. The composer began with the following system:

We take three arbitrary symbols or numbers, for instance 0 1 and 2. With three bits we have 27 unique

configurations. This provides us with an alphabet and a spare representation for a dot or a space.

. = 000

A = 001

B = 002

C = 010

D = 011

E = 012 and so on.

We take a short piece of text and encrypt it. The encryption is then transmitted as claps in rhythm: a 0 as a crotchet beat, a pair of quavers as a 1 and a triplet as a 2. We can now tell a joke by clapping!

The conductor removed the instruction specifying clapping and the premise translated in the form of a game, with the players taking it in turns to be the executors and interpreters. The players compete against each other as pairs: one player has to transmit a word or a clue to her team mate before the opposing pair can intercept it. The transmitting player is given the message encoded visually and some kind of musical instrument, preferably ridiculous in nature. She can then choose how to perform the three different sounds she needs, and hope her team mate can work out which sound, pitch or rhythm represents which symbol.

The game was tested a few times by guests at dinner parties. It is possible, hilarious, but difficult. There are many improvements that can be made, and should be tested at more dinner parties.

Eratosthenes



The sieve of Eratosthenes is an ancient Greek algorithm for finding prime numbers, which works excellently as a compositional framework. The first unmarked number after 1, mark as prime, move as many spaces along again and mark as composite, repeat this until the end. Return to zero and start again.

For this large body of work we have Eratosthenes of Cyrene to thank, who died in 194 bce. For such a visual sounding simple set of instructions I am shocked that there is not more art produced from it. The sieve reveals to us implicit universal and eternal truths about prime numbers that transcend language and numerical systems. We have no method for predicting prime numbers, but they can only appear in the spaces left by the patterns of composites created by the previous prime numbers. Like a three

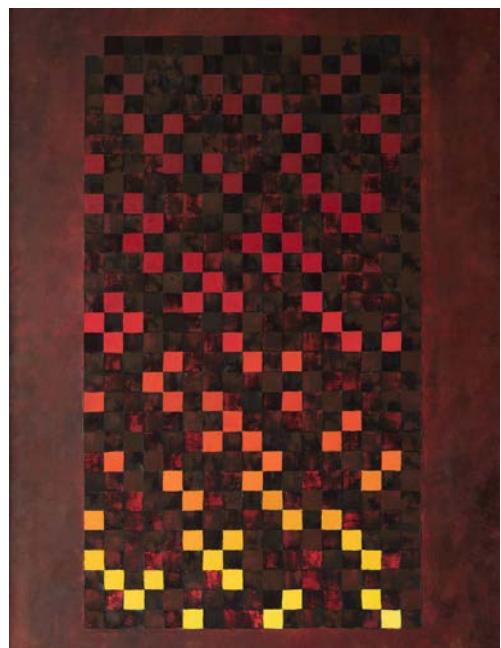
dimensional object, we can see these patterns from different perspectives depending on how the number line is interpreted. For this composition the conductor has to fill in the gaps of the calculations, the material aspect, but also what space the number line of real numbers occupies and the line of prime numbers.

Paul Ashwell's approaches to the sieve algorithm convey to the interpreter the construction of composite numbers from primes using new symbolic languages, sometimes very joyful in their nature. The work *Prime Marks 2010*[3] itself is a conductor which creates a new work of art every time the individual tiles are arranged according to space or the interpretation of the number line. The prime numbers are represented by symbols which feature in the composite numbers they are part of.

Rune Mields interpretation, *The Sieve of Eratosthenes 1971*[4] uses a computer program as a conductor to present different manifestations of the natural number line arrangement with a binary determination to indicate whether a cell represents a prime or composite number. The first time The Puzzle Factory approached the sieve composition was in 2015. I had expected it to be a staple of the visual mathematics repertoire but had not come across anything beyond diagrams. I had been desperate to see this painting that had been gestating ever since reading about the algorithm. Using squared paper and pencil crayons I was learning enough to create my own arrangement of the composition. This was the first painting using this type of approach and at this point we had no tools yet to work with. It was decided firmly at this early stage for subsequent works the importance of the intangible

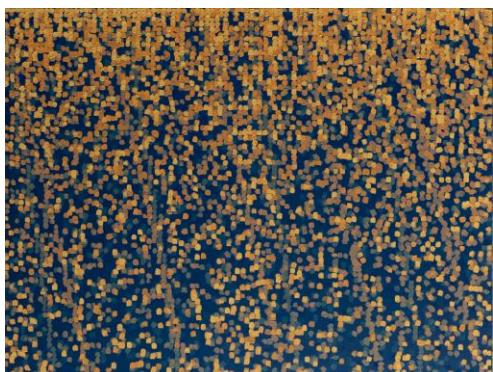
aspect, that perfection only exists in the abstract and should not be encouraged: mistakes will be made. That we keep it simple. The number line represented as a grid reading left to right top to bottom. With each prime number, the colour should change by small but visible increments: changing hue and changing from dark to light. I was vague about whether each prime would have its own colour to be recognised in the composites or alter in lightness slightly. That the composition was our screen to be projected on, the laborious painstaking process a method for reaching catharsis, like rocking or hyperventilating. The conductor was just a wobbly drawn grid and a list of prime numbers, the executor would have to do any calculations herself.

This style of painting was taking a risk for the executor. Each location of a composite number was literally calculated by counting squares and double checking. We had no model that would indicate how the composite patterns would form, how the finished piece would look or how the colours would interact. Because of the executor's integrity to the material aspect, all the paint is made by hand. It was laborious, painstaking and slow. It was very exciting to watch. We observed how the numbers as colours interacted in a dance, starting with subtle subtractive mixing to a vibrancy brought about by contrasts through to additive mixing bringing down the saturation.



Over time the conductor was improved, going from operations on spreadsheets to clumsy models made of vector graphic layers until I discovered how easy it was to code in JavaScript and HTML. The interpretations of number lines need not change. The tools for finding the right cell's co-ordinates was just a ruler and masking tape. Upon seeing a version of the composition in progress, visitors to the studio frequently made a disgusted face at wasting time on something nobody will buy and that we had nowhere to show.

Six years after the first version, exhibiting one at Bridges Waterloo, and selling them privately. I feel the rewards from our efforts have justified the expense and its about time to make another improvement to the conductor for a faster executing method.



Palindromes and spirals

The Puzzle Factory is not yet ready to fully implement its commercial and marketing strategies, so has to go on hiatus for months on end working with other arts organisations. These gaps can be useful gestation periods for future projects. After one such gap a mysterious new rule for the next generative projects involving discreet mathematics: change hue without changing lightness. I also found a technical challenge: traverse blue to yellow avoiding green or red. I feel no need to question these orders as I can trust that these are decisions reached after great scrutiny or may be worthwhile experiments.

Though it had become a unifying compositional element with the sieve, I was keen to ditch the grid no matter how wobbly it was. It had been a convention not a rule and was costing depth. It also smacked of ‘colouring in’ that may confuse the interpreter regarding technical ability and the Puzzle Factory’s policy about perfection.

Another house rule of the Puzzle Factory I felt was in danger was not to get lost in an abstract world; working with paint is well and good for a diagram, but there should be some anchor back to planet Earth.

The Puzzle Factory now had specialised tools for modeling and testing compositions through adaptable JavaScript functions. We had an adequate conductor in the form of another simple bit of software and thanks to preparation and opportunity, all the pigment we needed for the next twenty years. Now we had the first version of an analogue x y plotter full of character, made of junk with an accuracy that could be adjusted and a desk ideal in size.

Two paintings from observations of the local flora and struggles with our small container garden influenced our next projects.

Two trains of thought met serendipitously in a new composition exploring palindromic numbers. The execution was more ambitious and uncompromising than any we had tried before. One of the Eratosthenes paintings had used the smallest possible palette knife with paint made in a particular way that made it behave mischievously. The support was a 50 by 38 inch canvas representing 12,192 cells, iterated over 35 times. The mysterious colour rule and the number of iterations called for almost pharmaceutical paint making and mixing. Each rule was as though it had been chosen to push the limits of the executor, but thanks to the computer model their necessity was unquestionable as was the need for it to be painted by a confident human hand. The title is *2nd February 2020*. As with the sieve it felt as though surprising and beautiful secrets were being revealed to us, probably trivial to a student of number theory, but may not have been appreciated had not every single palindromic number been combed through in this way.

Another, more familiar composition was being arranged during this time. Getting

further from the grid it dispersed the number line in a spiral according to the rules of phyllotaxis and applied colour according to properties of the number. The computer struggled with rendering the model, it was getting old, so a complete picture was not available but we could at least see that the calculations would be correct.

There are two spiralling sequences taking place in the painting. One inhabits a three dimensional space, the other two. One's leaves expand, the other contracts. With each new 'leaf' on one, the value goes up by one, the other goes up by zero. The yellow to blue challenge could be dropped now. Obeying the lightness and hue rule, a palette based on sunflowers and using big friendly increments is used to represent Fibonacci numbers. Each 'leaf' has a numerical value and according to its divisors attributed a place in the spectrum and height in the illusory space indicated by its edge. The title is *If you don't stop eating my plants I'm going to eat you.*

This was not the first composition involving this sort of back and forth process where consecutive order of points is not immediately clear. A previous project had got so far as a conductor involving a program in python and a cheap projector, theoretically this may be the best method but just did not work at the time. Using the conductor system from the previous projects was found to be adequate but not ideal. The execution could have benefited from some way of painting circles that pushed the paint out from the centre instead of round the circle.

The end result fulfilled the paintings objectives and revealed surprising qualities about these numbers that I had

failed to understand with previous demonstrations. Not only academic but otherworldly and about to become more hypnotic when the intentions around presentation were discovered.

Presentation

Presentation has to be sympathetic to the various aspects of the artwork as well as the environment it inhabits allowing a transition from one world to another. Part of the Puzzle Factory premises is for small exhibitions with the intention of preparing work for larger exhibitions elsewhere. The beauty of a gallery is that it is an environment that can be controlled and adapted. There is no rule that says the walls must be white and the lights bright even though gallery owners may believe that. The theory for the presentation had been planned long before it could be tested. Between then and the completion of the paintings, light bulbs that change colour became cheaper and widely available. The intensity of the hues in the paintings have to be seen by the human eye to be believed.

Under normal light conditions, the paints made and used at the Puzzle Factory behave unlike other paints already. This is down to controllable factors in their chemistry and their application. With the simple changing colour of the light, paintings that were static inanimate images disappeared, then came to life, the different iterations and steps in the sequences revealing themselves in strange luminosities. If I had been conscious of the intention to shine changing coloured light from the beginning I would have objected on gimicky grounds, but I was pleasantly surprised to see all the painstaking and

intricate process come back again in elegant waves.

References

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[2] Exploring symmetry in rosettes of Truchet tiles, Andreia Hall, Paulo Almeida and Ricardo Teixeira, Journal of Mathematics and the Arts 2019 vol 13 NO. 4 p308

[3] Paul Ashwell. Prime concerns: painting number patterns. Journal of Mathematics and the arts 2020. vol 14 nos 1-2.

[4] Rune Mields, The Sieve of Eratosthenes 1971. Lynn Gamwell Mathematics and Art a cultural history.