Research Assessment Exercise 2020
Impact Case Study

University: City University of Hong Kong
Unit of Assessment (UoA): 11 Mathematics and Statistics

Title of case study: Art and Mathematics: reaching the general public

(1) Summary of the impact

The affinity between mathematics and the general public has always been limited. The discovery of a new material or the invention of a new vaccine, to mention just two instances, reaches the interest of the general public in a much stronger way than the proof of any longstanding conjecture. At the core of this impact case is the attempt to improve this situation by exploiting the relationship of mathematics with art, the latter being of universal interest. This is pursued through a book (that explains some of these relationships) and an art piece (that visualizes a particular mathematical subject).

As a result of this endeavour, thousands of people - attending art exhibitions and public lectures, or simply reading a book - have been interested on mathematical notions through art appreciation. For many of them, both their perception of what mathematics are and their way of approaching art pieces have been radically changed.

(2) Underpinning research

The research underpinning this case study has an interdisciplinary essence and partners mathematics with arts and humanities. Its corresponding body of research consists of two items of a very different nature: a book and an art piece, both by Professor Felipe Cucker (the second in collaboration with media artist Hector Rodriguez). This is in accordance with the practice of humanities (where books are at least as prized as articles) and arts (where the ultimate output is the creation of an art piece) and with the Framework of the RAE which includes both as research output in its point (14). In both cases, therefore, and as it happens in the more common instances of the interaction of mathematics with e.g., physics or economics, mathematics plays a key role in explaining or motivating a given phenomenon but the research is not mathematics in its own right.

The book *Manifold Mirrors* [MM] describes various facets of the relations between art and mathematics from a viewpoint encompassing both mathematics and humanities. The starting point is the observation that artists, along history, have created their works under external constraints. These constraints can be religious (the need to adjust to a given narration), social (the interdiction to depict nudity in various societies), formal (the strictures of meter and rhyme in versification), … Among the formal constraints it is not uncommon to find some with a mathematical nature. *Manifold Mirrors* focuses on two families of such constraints: the use of various forms of symmetry and the use of various forms of projection (of a 3-dimensional scene onto a 2-dimensional surface). Whereas the latter is considered only for a few visual arts (painting, photography, film) occurrences of the former are examined, in addition, in other art formats such as poetry, music, carpet weaving, furniture, and dance. A main theme is the classification of mathematical structures (such as symmetry groups) which translates into a catalogue of formal choices for the artist. A complementary theme is the catalogue of perceptual effects associated to these structures and the way artists have creatively used this association to obtain particular visual effects.

The art piece *Approximation Theory* [AT] is an art-research project in visual mathematics and data aesthetics. It is a genuine collaboration between a mathematician (Cucker) and a new media artist (Rodriguez) and consists of a series of prints and videos that visualize some basic ideas in the mathematical theory of approximation as summarized in Chapters 1 and 2 of [LT]. It is based on the fact that an image (say in black and white, with *N* pixels) can be seen as a point in *N*-dimensional real space. Given an image *J* and a collection of *k* other images, called lexicon, we can consider the projection of a given image onto the linear space spanned by these *k* images. This projection is the best (w.r.t. the L2 norm) reconstruction of *J* "in terms of" the images in the lexicon. *Approximation Theory* focuses on two aspects of these reconstructions. The quantitative aspect visualizes how the reconstruction sharpens when *k* increases. This is a common theme in the mathematical theory of approximation which in this context has a powerful visual content. Interestingly, it also connects with the dichotomy between seeing-in and seeing-through that is a subject of study in art theory (see Chapter 1 in [Dominic M. Lopes, S*ight and Sensibility: Evaluating Pictures*, Oxford University Press, 2015.]). The qualitative aspect visualizes how the character of the reconstruction changes when the lexicon changes. Again, this corresponds to choosing a particular family of approximating functions, which is a common theme in the mathematical theory of approximation. *Approximation Theory* uses four different lexica: lines, circles, Chinese characters, and frames from a film (*Alphaville* by J.-L. Godard). These are examples of elements for the first three:

They produce remarkably different reconstructions.
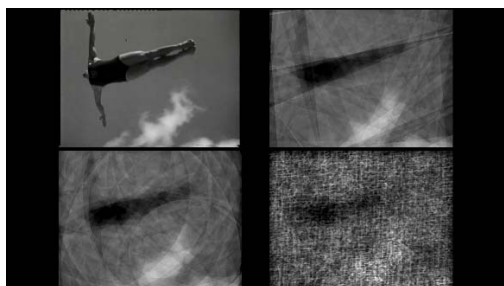
The setup of the art piece varies. The most common includes prints with different reconstructions and a video with a grid: four rows corresponding to the four families of lexica and six or seven columns corresponding to different sizes of the lexicon. The video reconstructs short clips taken from the movie *Olympia* (Leni Riefenstahl, 1936) which do not have any reliance neither on sound nor on narration; they are, in a sense, pure motion. This fact allows the viewer to focus on the reconstruction without having her attention distracted by aspects of the images alien to the reconstruction itself.

(3)   References to the research

[MM] Manifold Mirrors
        Felipe Cucker, *Manifold Mirrors: the crossing paths of the Arts and Mathematics*, Cambridge University Press, 2013

[AT]   Approximation Theory
       http://concept-script.com/approxTheory/index.html#

[LT]   Learning Theory
       Felipe Cucker and Ding-Xuan Zhou, *Learning Theory: An Approximation Theory Viewpoint*, Cambridge University Press, 2007

(4)   Details of the impact

Manifold Mirrors was awarded two distinctions: an Honorable Mention in the PROSE awards 2013 in the category "Mathematics" [1] and the selection as an Outstanding Academic Title 2014 by the magazine *Choice* [10]. The PROSE awards are given by the Association of American Publishers [2] which, quoting Wikipedia, "is the national trade association of the American book publishing industry." The magazine *Choice* is published by the American Library Association. Citing their website [3], "Every year in the January issue, in print and online, *Choice* publishes a list of Outstanding Academic Titles that were reviewed during the previous calendar year. This prestigious list reflects the best in scholarly titles reviewed by *Choice* and brings with it the extraordinary recognition of the academic library community." In addition to the above, the publication of *Manifold Mirrors* attracted some media coverage. On October 6th, 2013, the South China Morning Post (the leading English language newspaper in Hong Kong) published an article about Cucker featuring, among other themes, the subject of *Manifold Mirrors* [4]. At about the same time, on October 7th, Cucker gave a talk on Mathematics and Art at the Café Scientifique in Hong Kong (in their own words, "a place where, for the price of a cup of coffee or a glass of wine, members of the public can come to explore the latest ideas in science and technology with top scientists from around the world"). The social reach of *Manifold Mirrors* also extended to secondary schools: on February 19th, 2014, Cucker gave a talk to more than a hundred IB students (form 5) at the Creative Secondary School and, on October 4th, 2016, he did so at the Hong Kong Academy (another secondary school in Hong Kong). Students at this school were working on a mural with an Art and Svcience theme and "were energised by [Cucker's] talk to explore more about these drawing techniques as they planned their mural" (see letter in the attached documents). He also gave talks at the Puerta-Roja art gallery, on June 3rd, 2016, and at the Kee Club, on September 6th, 2016, within the space "Science Rendez-Vous" organized by the French General Consulate in Hong Kong. Some evidence of the impact of these talks is also provided in the attached documents. As of today, *Manifold Mirrors* has sold around 2000 copies.

The impact of *Approximation Theory* can be gauged from the fact that, after its creation, it was quickly accepted in three international art festivals. One of them, the XX Generative Art Conference/Exhibition (Ravenna, Italy, December 2017, see [5]) is widely considered to be the major exhibition of generative art. The other two, the RIXC Art Science Festival (Riga, Latvia, October 2017, see [6]) and the 14th Athens Digital Art Festival (Athens, Greece, May 2018, see [7]) are broadly conceived, highly selective, new media art festivals. These festivals are held in public landmarks (The Museum of Art in Ravenna, the Contemporary Art Centre in Riga, and the Megaron Athens Concert Hall) and are open to the general public. The municipalities of Riga and Athens widely advertise them and, as a consequence, they are attended by thousands of people. A video produced after the 14th Athens Digital Art Festival [8] gives an idea of the atmosphere at that festival. An idea of its quality and impact can be obtained by looking at a few numbers (taken from [9]): there were 4237 artist's submissions of which 350 were selected from artists coming from 60 countries; more than 20,000 persons attended the exhibition.

Additional supporting documents can be found in [10].

(5)   Sources to corroborate the impact

[1] PROSE Awards winners 2013
     https://proseawards.com/winners/2013-award-winners/

[2] PROSE Awards
     https://en.wikipedia.org/wiki/PROSE Awards

[3] ALA Outstanding Titles
     http://www.ala.org/acrl/choice/outstanding

[4] Press interview
     http://www.scmp.com/magazines/post-magazine/article/1323464/my-life-felipe-cucker

[5] Generative Art Exhibition
     http://www.generativeart.com/GA2017/GA2017_index.htm

[6] RIXC Art Science Festival
     http://festival2017.rixc.org/festival-exhibition/

[7] Athens Digital Arts Festival 1
     http://2018.adaf.gr/program/?language=en&date=all&category[]=digital-image

[8] Athens Digital Arts Festival 2
     https://www.youtube.com/watch?v=tAKIS46pNyk

[9] Athens Digital Arts Festival 3
     http://2018.adaf.gr/news/what-we-saw-at-the-14th-athens-digital-arts-festival/

[10] Supporting documents
     http://www.cityu.edu.hk/ma/research/10_Supporting_documents.pdf