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An Ethnomathematical Study of Sand-Drawing in Vanuatu

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Abstract. In the central islands of Vanuatu (former New Hebrides), it exists a practice of drawing symmetrical figures on the ground, according to rules that make it very constrained and that allow the practice to be interrogated to highlight its “mathematical dimension”. Based on a survey carried out between 2016 and 2019 within the Raga society of the Pentecost Island, and a rereading of the Marcia Ascher’s work, I introduce in this article a new mathematical model and IT-tools computed in Python to reveal the operative and algorithmic nature of this practice. The ethnographic data led me to introduce several concepts that seem to be at the very core of the acts of creation and memorization of these drawings. These modeling tools allow us to question the practice of sand-drawing in Vanuatu societies, not as an isolated fact, but as a revelation of their way of inhabiting the world.

Keywords. Sand-drawing, Ethnography, Modeling, Graph theory, Python.

Introduction

The study of sand-drawings relates to societies in Vanuatu, an island-nation in the Pacific which was colonized by both France and England.

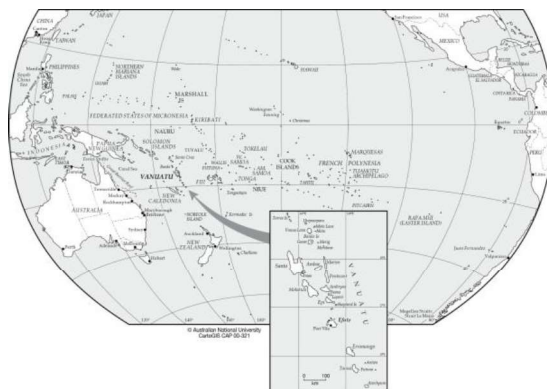


Figure 1. Vanuatu.

The making of drawings made up of a continuous line drawn on the ground has been observed throughout the 20th century by ethnologists in different cultural areas. For example, they are created among the Tchokwe in Angola where they are called “sonas” (Fontinha, 1983; Kubik, 1987), the Tamils of Tamil Nadu where they are called “kolam” (Nagarajan, 1998; Steinmann, 1989), and in certain Melanesian societies of the South Pacific (Deacon, 1934; Layard, 1942). In the central islands of Vanuatu¹, the practice has vernacular names that suggest the notion of writing (such as Uli-Uli at Pentecost). More generally, it is called “sandroing” in Bislama (the local lingua franca) and “sand-drawing” in English. Although there may be some variations from one island to another, common features can be listed. After having drawn a “grid” on a ground covered with sand or ash, the practitioner traces a line through it with a finger, which rarely lifts off the ground during the making of the drawing and which does not continuously pass over a part that has already been drawn. After the drawing is finished, the index finger is, in a very large number of cases, returned back to the starting point and in the same direction. All these features make this practice all the more constrained as most of these sand-drawings generally have one or more axes of symmetry. Grids act as a frame and can come in many shapes and sizes. Rectangles, assemblies of rectangles or circles, their shapes seem to be limited only by the creativity of the experts.

¹Named “the New Hebrides” by the English navigator James Cook in the 1770s, this archipelago was administrated by a Franco-British colonial condominium from 1906 until its independence in 1980, when it became the Republic of Vanuatu, whose three official languages are Bislama, French, and English. Given the 120 vernacular languages spoken locally in the country (for about 250,000 people), Bislama plays the role of a lingua franca.

This ephemeral art –the drawing being erased once finished – is a medium that stimulates narration, and experts usually conclude their drawings with a narrative of a myth or a tale. As we mentioned in a recent article, “nowadays, the practice of sand-drawing is recognized as a traditional graphic art within the societies concerned – a mnemonic dimension involved in the recollection of ritual, mythological, and/or environmental knowledge, considered as part of the *Kastom*² ” (Vandendriessche & Da Silva, 2022, p. 2). In many cases, each design has a vernacular name related to its various aspects.

Theoretical Background

The practices of “continuous lines” have drawn the attention of some mathematicians, notably Paulus Gerdes and Marcia Ascher, whose contributions to the field of ethnomathematics are considerable. Gerdes intended to “reconstruct” the “frozen” (or “hidden”) mathematics that the practice of *sonas* could stimulate (Gerdes, 1986, p.12). As far as Marcia Ascher is concerned, she has focused on a research axis questioning the relation between her mathematical models and the point of view of the practitioners holding knowledge or know-how of the sand-drawing of Vanuatu (Ascher, 1988, 1991). By introducing a formalism involving two concepts – process algebras and Eulerian graphs – she intended to uncover the logical structures underlying the making of sand-drawings. Certainly, the Vanuatu drawers do not store or conceive their drawings using formulas. But it is now one of the classic methods of ethnomathematics to introduce a formalism that allows researchers and the practitioners to uncover phenomena that might “otherwise escape us” (Ascher, 1991, p.48).

Ascher’s contribution to the study of sand-drawing in Vanuatu provided an ideal starting point for my work. In particular, I have shown that since she had worked on second-hand data, important practical characteristics has not been taken into account in her model. This prompted me to draw inspiration from the methods developed in recent works, privileging multidisciplinary approaches to study cultural practices such as the divinatory arts *Sikidy* in Madagascar (Chemillier et al., 2007) or the *string-figures* on the Trobriand Islands in Papua New Guinea (Vandendriessche, 2015). These works combine the methodology of the ethnologist immersing himself in a society to conduct an ethnographic study and that of the mathematician creating a formal model based on empirical data.

Methodology

The Ethnomathematical Method of Inquiry

In my PhD (Da Silva, 2022), I have chosen to focus my study on a society inhabiting the north of the island of Pentecost, named *Raga* ([Ra-ra]), that has been studied in the field of anthropology (Taylor, 2008; Yoshioka, 1987), and whose language² has drawn the attention of linguists (Duhamel, 2020; Vari-Bogiri, 2011). A fieldwork conducted in this society between 2018 and 2019, has led me to gather a corpus of about sixty drawings, most of which were filmed and discussed with practitioners. It should be noted that there exist different levels of expertise, the *Raga* experts being generally recognized as such by the members of this society. The ethnographic approach that has been favored is holistic, that is to say that it does not neglect any fact, even those that may seem, at first glance, to be unrelated to sand-drawing. Indeed, to figure out the mathematical dimension of this practice, it would not have been relevant to reduce the sand-drawing to a self-contained system. Indeed, it has been fruitful to understand its place within a system that includes myths, cosmogonies, kinship ties, ontologies or any other social facts. The systematic collection of the lexicon related to the sand-drawing turned out crucial in developing the model. This ethnolinguistic approach has shown that many words used by practitioners are common to the lexical field of the construction (for those of traditional houses for example). In addition, as highlighted by work in cognitive anthropology, “it is not even necessary for this type of knowledge ever to be put into words for it to be transmitted from one member of the community to another” (Bloch, 2018, p.13-14). Particular attention was then paid

²“*Kastom* is the word that people in Vanuatu use to characterize their own knowledge and practice in distinction to everything they identify as having come from outside their place” (Bolton, 2003, p.13)

³The *Raga* language (of the same name) counts approximately 7000 native speakers

to the gestures of practitioners, and the speed of execution or, on the contrary, the hesitations, the mistakes and their corrections have turned out to be valuable ethnographic material.



Figure 2. Ngavulu (“Number 10”) – North Pentecost –2019.



Movie 1: Clickable link – Dam Vwari – Pentecost islands (2019).

A New Mathematical Model

In order to account for the cognitive aspects brought into play during the creation and execution phases of the drawings, the model must be as faithful as possible to practice. The analysis of the materials led me to develop two key concepts: the concept of “motion group” and the concept of “modeling graph”. These two concepts are based on the idea that the movement of the designer’s finger goes through a set of nodes of the grid, but also a sequence of directions in each of these nodes, which can take only four values (see Figure 3). Therefore, it is convenient to work in the space $E = \mathbb{Z}[i] \times U_4$, where $\mathbb{Z}[i]$ is a model of an infinite grid, and U_4 is the cyclic group of four elements. A motion between two nodes is then modeled by a map from E to E . In the same way that we can distinguish a vector of the plane from its representatives, we must distinguish the motions from their representatives which are the curves drawn by the practitioner: a motion is the equivalence class of all the curves that represent it. This formalism was introduced to account for the way in which some designers have experimented the possibilities of using different representatives of a motion, without impacting the global structure of the design. As this set of maps turns out to be a group, we can perceive the algebraic aspect of the practice, since the designer’s finger “acts” (in the sense of group actions) on E . This model could be relevant and close to the point of view of the actors, since many motions (or sequences of motions) are given vernacular names.

Each drawing can then be written as a “word” $m_1 m_2 \dots m_N$ where each m_i is such an application, and it is then possible to consider a new graph that results from the relation between the vertices, in a different way than the one Ascher had imagined. The main idea is to associate to each node S of the grid, not one, but two vertices of the graph (S, \nearrow) (in red) and (S, \searrow) (in blue). The red vertex is associated with the direction carried by the first diagonal, and the blue vertex to the second diagonal. There is then an edge between two vertices (S, d) and (S', d') of G_{mod} if there is a movement of the drawing which starts from S in the direction d and which arrives in S' in the direction d' (see Figure 4).

This graph (called G_{mod}) is Eulerian (Da Silva, 2022) and, according to the Veblen’s theorem (Veblen, 1912) this set of edges can then be written as a union of disjoint cycles. The concept of *cycle*, adapted to sand-drawing takes the following meaning: a *cycle* in a drawing is a closed path that crosses the grid and comes back to the starting point in the same direction. When a drawing is written as a “word”, an efficient algorithm computes all cycles drawn by the practitioner (see Figure 5a).

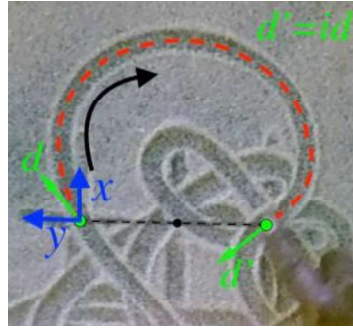
Results

The analysis of the gestures and the experiments led with the experts show that cycles, and the order in which they are traced, are at the very core of the process of memorization and creation of sand-drawings. In addition, I have highlighted particular cycles that “cover the whole grid”, named *trellis* by ethnographers such as A.B Deacon (1903- 1927) because of the crossings they make appear at each node of the grid. The sizes of the grids allowing to execute these trellis must satisfy particular

conditions, which seem to be known in some way by the experts. Since the execution of such cycles can be written as real algorithms, I named one of them "turtle algorithm" and denoted $T(r, c)$ where r and c are the number of horizontal and vertical lines c . I proved that this algorithm covers the whole grid when c is odd and $\gcd(r, c)$ is 1. Some experts seem to know this result in particular cases (for $c = 3$ for instance). Other processes of drawing can be analyzed as algorithms, and in particular one which allows to "represent" each number of the Raga numeration (see Figure 2).

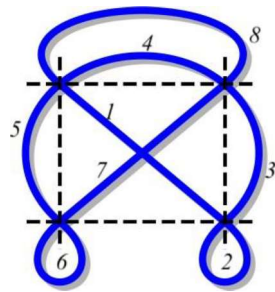


(a) Each node is crossed in one of 4 possible directions.

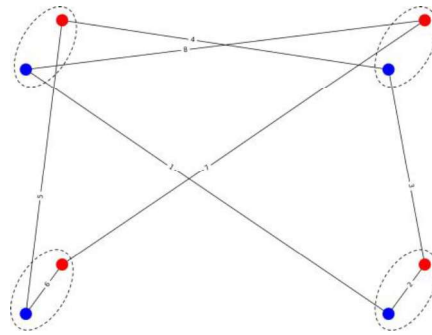


(b) An example of motion

Figure 3. The three-dimensional model: two in the plane, one more with the directions taken at each node.

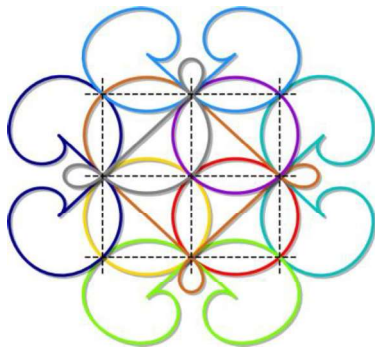


(a) A drawing from Malekula (in (Deacon, 1934))

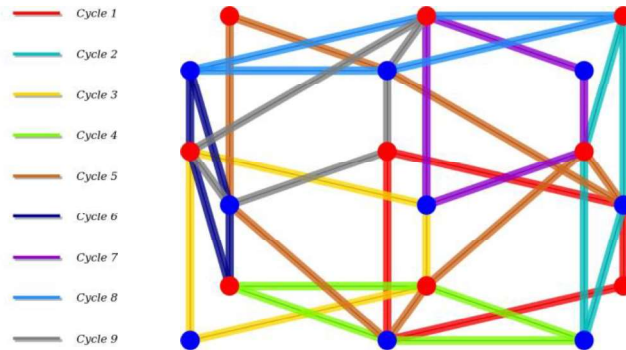


(b) The graph G_{mod}

Figure 4. The G_{mod} graph being a cycle, the drawing is then called a *treillis*.



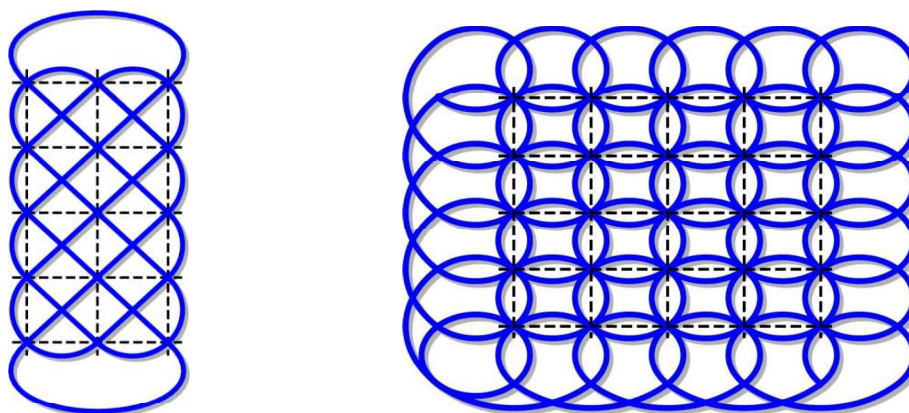
(a) A decomposition into disjoint cycles given by an algorithm written in Python.



(b) The corresponding graph G_{mod}

Figure 5. Modelling with Python computer program.

Finally, the experts seem to have imagined various intellectual tools such as those I have analyzed as "topological operations of connection", but which it would not be possible to describe here in this short paper (Da Silva, 2022, Chapter 4).



(a) $T(5, 3)$, the "turtle algorithm"

(b) The "number algorithm"

Figure 6. Creating the various curves using algorithms.

Conclusion and Discussion

In this paper, we have briefly presented some aspects of the work I carried out in my PhD. This one is essentially based on a multidisciplinary approach, mixing ethnography and modeling. This method proved to be fruitful and allowed to renew the early ethnomathematical works on sand-drawing in Vanuatu. In this approach, the use of computers has been decisive not only to automate the decomposition of drawings into cycles, but also to experiment with new tracing methods, which can then be submitted to experts. The main result is that the motions, the sequences of motions, the cycles, some topological operations and some algorithms seem to play a key role in the cognitive process engaged in the creation and memorization of sand-drawings, which could be *prototypical* of the mathematical thinking, in the sense defined by psychologists such as Sternberg (Sternberg & Ben-Zeev, 1996). It should be kept in mind that the model is certainly far from the actors' point of view, but the approach that has been privileged uses mathematical language to highlight the ingenuity of the practitioners who, let us remember, do not rely on writing to memorize the drawings.

These results open up several new avenues and it would be a question of understanding in what way the operative variations observed in the field, for example between two neighboring islands such as Pentecost Island and Ambrym Island, are constitutive of certain cultural variations. Finally, as pointed out in our recent article (Vandendriessche & Da Silva, 2022), this type of work could contribute to the discussion that has been underway in Vanuatu for the last decade or so, aiming to reform school curricula with the objective of locally implementing teachings that take more into account the country's many cultural and linguistic contexts. Indeed, school institutions consider the pedagogical use of sand-drawings (as well as other algorithmic and/or geometric practices) to provide culturally meaningful mathematics education.

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