# *Algorithms. Anamorphoses. Anomalies*: Using Mathematics to Make a Dance Performance

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## Abstract

This paper discusses the multidisciplinary dance performance *Algorithms. Anamorphoses. Anomalies* by Olga Sevostyanova and Eka Zharinova. It traces the influence of methods such as Real Time Composition by João Fiadeiro and the 3Q System by Iztok Kovač, and works by Trisha Brown, such as *Accumulation*, to deliver our little discoveries on the possible use of mathematics in dance making which became a basis of the piece.


## Multidisciplinary Performance *Algorithms. Anamorphoses. Anomalies*

*Algorithms. Anamorphoses. Anomalies* (2012) is a duet dance performance co-created by myself and Olga Sevostyanova, my long-time colleague, collaborator, and friend [12]. It was our first experience doing practical research on dance and mathematics: we examined possible connections between the disciplines and explored how they can be presented in the form of a dance performance. The resulting dance performance comprised a sequence of movements that developed algorithmically. As part of the performance we also wrote mathematical formulae and chaotically applied acrylic paints to rolls of paper that initially hung from the ceiling. The title refers to the fact that the performance is built on algorithms, aims for visual anamorphoses, and embraces some of the anomalies that emerge in the process.

## Dance Using Mathematics: The Beginning and Possible Influences

I graduated from university with a Master of Science in Mathematics in 2001; at the time, I was dancing full-time with the Provincial Dances Theatre. Feeling I had to choose between the two disciplines, I chose to devote myself to dance. For many years after, while I desired to combine dance and mathematics in my artistic practice, it seemed to be impossible. Only in 2011, while attending AND_Lab, did I understand how dance and mathematics can be connected. AND_Lab is an artistic research and scientific creativity laboratory, founded by João Fiadeiro and Fernanda Eugénio at the Atelier RE.AL in Lisbon in 2011.

At the AND_Lab in which I participated, the Portuguese choreographer João Fiadeiro (b. 1965) introduced his Real Time Composition method, which he has been developing since the 1990s. His method is “a system of principles and values to be used with his collaborators in the process of choreographing” [3]. I found the way he explained this system mathematical: artistic choices made at each step in the creation process were based not on someone’s aesthetic preferences but instead resulted from the method’s systematic approach. This avoidance of individual bias and rigorous analytical engagement related to what I had experienced and appreciated while studying mathematics: “Exactly because composition […] only happens because it emerges (or only emerges because it happens). […] Nothing happens if there isn’t the participation of more than one agent (even when we are alone)” [2]. Everyone is involved in the composition, which unavoidably impacts the end result; and because actions are based upon the preceding ones, an initial event is essential and, crucially, needs to have potential. “...it’s required that the players do at least three positions, which generates two relations: one between the first and the second positions and [the] other between the third and the relation between the first and the second” [2]. Being a part of a Real Time Composition practice requires heightened awareness of what is being uncovered during the practice in time and space, in order to constantly (and attentively) calibrate whether to make a move (or not), and which one. At the AND_Lab, I genuinely enjoyed implementing these scientific principles which unified cognitive engagement and the physical creative process. After the lab, my objective was to bring cognitive elements into my dance-making practice through the application of mathematics to dance. Together with my colleague, we focused on set theory, the branch of mathematics that studies the general properties of sets, where the set is a collection of well-defined and distinct objects—in our case, dance moves.

The conceptualisation of a dance phrase as a set of movement elements could also be a consequence of my participation in the dance composition workshop led by the Slovenian choreographer Iztok Kovač (b. 1962) at the Moscow Summer Dance School TsEKh in 2005. At the workshop, Kovač operated with motion units, introducing the 3Q system which he invented in 1993. He explained in our subsequent email conversation that the 3Q system was inspired by the John Zorn music composition, "You Will Be Shot," from the 1990 album "Naked City," in which "three themes are exchanging as a main compositional line" [5]. As music critic Jon Pareles wrote at the time, "Since the mid-1970's, Mr. Zorn has been putting together groups of improvisers to perform pieces that unfold in discrete, unpredictable segments. Many were organised like games, with rules and signals and timekeepers to determine who played (the game or piece) and how" [6]. Similarly, in the 3Q system, dancers create a playful composition in which each motion unit in their dance sequence is determined by their "react[ion] to the leader's performance using three options, which are pre-chosen by throwing the dice" [4]. This division of a dance phrase into units (or the building of a dance phrase piece by piece) and the separate manipulation of each piece, influenced my later approach to movement sequencing in dance whereby I can determine what piece or motion unit comes next at each transitional moment, or apply a rule or transformation to a set or subset of motion units.

The follow-up movement research that Olga Sevostyanova and I did in 2012 reminded me aesthetically of the early work of American choreographer Trisha Brown (b. 1936). In *Accumulation* (1971), which was particularly influential, Brown literally accumulated movements into a constantly growing movement sequence while standing in one place. As she described, "…*Accumulation* is stationary and consists of the methodical build-up of carefully chosen gestures. I begin with one gesture, repeat it about six times, add 3 to 2 and 1, et cetera" [1]. I was attracted to the work because it is "monumental in its simplicity" [1], and while the performance seemed laconic and translucent, its concept felt hugely insightful. Susan Rosenberg aptly expressed the piece's search for balance between engagement in bodily movement and a cognitive process, stating that it "exposes the cognitive challenge of performing, showing the dancer and the body in the course of thinking, not merely gesturing in space, and offers the satisfaction of watching a composition materialize according to an indissoluble unity of intent and action" [8]. Writing for *Dance/USA*, Wendy Perron noted, "The dance is incredibly sensual to do and to see, and yet the accumulation score keeps the mind strictly focused" [7]. This strict balance is precisely what I appreciate in Trisha Brown's artwork; the combination of witty concepts with enticing movements is very appealing to me.

## Connecting Dance to Mathematics in *Algorithms. Anamorphoses. Anomalies*

The act of accumulation can be represented as an iterative algorithm. In a dance context, movements are added at each step of the algorithm to form a set of movements or, to be more precise, a sequence, which is an ordered list of objects where the same elements might appear multiple times at different positions. In mathematical symbols the accumulative process can be described as follows:

$$A_0 = [\gamma_0],$$
$$A_i = A_{i-1} + [\gamma_i], \text{ where } A_i = [\gamma_0, \gamma_1, \gamma_2, \ldots, \gamma_i] \text{ for } i = 1, 2, \ldots, N.$$

Here, $\gamma_0$ is a neutral start position, which is a null movement (e.g., lying on the floor with arms alongside the body), and $\gamma_i$ are movements added on each iteration at the end of the growing dance sequence, i.e., "+" denotes concatenation of two sequences. Accordingly, $A_i$ are built from $i$+1 consecutive movements $\gamma_0, \gamma_1, \gamma_2, \ldots, \gamma_i$ for $i = 1, 2, \ldots, N$. Using the iterative algorithm, we gradually obtain the sequence of movements, $\Gamma = [\gamma_0, \gamma_1, \gamma_2, \ldots, \gamma_N]$. Each element's position in Γ's notation determines its position in this dance sequence. Hence, $\gamma_0$ is the starting position, followed by movements $\gamma_1, \gamma_2, \ldots$, and the last movement is $\gamma_N$. There is a naturally occurring constraint in this process; namely, that in a sequence of movements, the end position of a movement needs to equal the start position of the following movement. This process was illustrated in the video, "Creating a Set of Movement" [10].

In *Algorithms. Anamorphoses. Anomalies*, the choreography included a dance sequence of accumulated movements that Olga Sevostyanova and I proposed in turn during the performance. First, we wrote the explanation of the iterative process on rolls of paper hung from the ceiling, using mathematical symbols similar to those described above. Then, we created the sequence in front of the audience. The generated dance material therefore contained an element of surprise for both of us dancers, since we could not know which movement would come next. Each motion unit was indexed according to its order in the sequence: each time we added a movement, we repeated the sequence from the beginning, including the new movement at the end, which helped us better memorise the growing sequence.

During *Algorithms. Anamorphoses. Anomalies*, we established inverse and symmetrical movement transformations. First, let's denote $\phi$ as a transformation on the set of dance sequences $\mathbb{\Gamma}$:

$$\phi : \mathbb{\Gamma} \to \mathbb{\Gamma}$$

Then, we can consider two transformations: $\phi_1(\Gamma) = \Gamma^{-} = [\gamma_N^{-}, \ldots, \gamma_1^{-}, \gamma_0]$ is an inversion in which each motion unit, and the order in which they are performed, is inverted, that is to say, performed as if time is reversed, sometimes called retrograde form. $\phi_2(\Gamma) = -\Gamma = [\gamma_0, -\gamma_1, \ldots, -\gamma_N]$ is a symmetrical transformation (in this case, reflection symmetry) that can be represented as the left-right mirroring of motion units along the longitudinal or sagittal plane of the body. Motion units are conducted in the same order. If performed in a duo, when one dancer implements a dance sequence and the other dancer performs the sequence's symmetrical transformation, the audience can see the movement reflected in relation to the plane imagined between the dancers. $\gamma_0 = \gamma_0^{-} = -\gamma_0$ is a null movement represented by a neutral position. $\phi_1(\phi_2(\Gamma)) = \phi_2(\phi_1(\Gamma))$—the operation of applying these two transformations consecutively is commutative; in other words, in whatever order the transformations $\phi_1$ and $\phi_2$ are applied, the resulting sequence is the same. Olga Sevostyanova and I illustrated the idea of transformations in the video "Transformations of the Set" [11]. What was presented in the video could be designated as:

$$\Gamma = [\gamma_0, \gamma_1, \ldots, \gamma_{12}]$$

$$\phi_1(\Gamma) = [\gamma_{12}^{-}, \ldots, \gamma_1^{-}, \gamma_0]$$
$$\phi_2(\Gamma) = [\gamma_0, -\gamma_1, \ldots, -\gamma_{12}]$$

$$\textit{Eka} : \Gamma + \phi_1(\Gamma) + \Gamma$$
$$\textit{Olga} : \phi_1(\Gamma) + \Gamma + \phi_1(\Gamma)$$

$$\textit{Eka} : \phi_2(\Gamma) + \phi_1(\phi_2(\Gamma))$$
$$\textit{Olga} : \Gamma + \phi_1(\Gamma)$$

$$\textit{Eka} : \phi_1(\Gamma)$$
$$\textit{Olga} : \phi_2(\phi_1(\Gamma))$$

I carried out further investigations at the Barcelona International Dance Exchange (BIDE). BIDE is an annual gathering of dance professionals that promotes horizontal participation dynamics. I facilitated a "Dance and Mathematics" lab there in 2012 in which I introduced the ideas described above and then together we created a set of movements using collective accumulation, whereby each dancer added one motion unit to the set. Once we had the set, we did two transformations—one inversion and one reflection—and performed their different combinations in quartets, like we did in the duet. The lab lasted a whole day; the resulting dance sequence was shared with other BIDE participants in the evening.

The sequence below describes what we presented at our sharing in the evening, which can also be viewed on the video recording, "BIDE 2012 Dance and Math Lab Showing" [9]. We started in a circle facing each other and for some time simply moved all together through the sequence described below. We then added transitions in space, changing the directions we faced and our positions in space according to timings that were not pre-set—these decisions were made individually during the sharing. The notion of a subset, as applied to a dance sequence, also arose in this workshop. By definition, set B is a subset of set A if B is "contained" in A, and A and B may coincide. Within the sharing, we performed an accumulation of subsets of the initial set of motion units and their inversions, loudly announcing the units: "igrek null," "igrek one," and so on. In this paper, instead of "igrek," the gamma symbol is used for the same purpose.

$B_0 = [\gamma_0]$
$B_1 = [\gamma_0] + [\gamma_1] + [\gamma_1^-] + [\gamma_0] = A_1 + \phi_1(A_1)$
$B_2 = [\gamma_0] + [\gamma_1] + [\gamma_2] + [\gamma_2^-] + [\gamma_1^-] + [\gamma_0] = A_2 + \phi_1(A_2)$
...
$B_{11} = [\gamma_0] + [\gamma_1] + [\gamma_2] + \ldots + [\gamma_{11}] + [\gamma_{11}^-] + \ldots + [\gamma_2^-] + [\gamma_1^-] + [\gamma_0] = A_{11} + \phi_1(A_{11})$
$B_{12} = [\gamma_0] + [\gamma_1] + [\gamma_2] + \ldots + [\gamma_{11}] + [\gamma_{12}] + [\gamma_{12}^-] + [\gamma_{11}^-] + \ldots + [\gamma_2^-] + [\gamma_1^-] + [\gamma_0] = A_{12} + \phi_1(A_{12})$

During the evening sharing, as a group we presented $B_1 + B_2 + \ldots + B_{11} + B_{12}$. Here, each dance phrase $B_i$ ($i = 1, 2, \ldots, 11, 12$) corresponds to two sets $A_i$ and $\phi_1(A_i)$, where $A_i = [\gamma_0, \gamma_1, \ldots, \gamma_i]$ is a subset of the set $\Gamma = [\gamma_0, \gamma_1, \ldots, \gamma_{12}]$, and $\phi_1(A_i) = A_i^- = [\gamma_i^-, \ldots, \gamma_1^-, \gamma_0]$ is an inversion of $A_i$.

In *Algorithms. Anamorphoses. Anomalies*, we worked with subsets and used the gamma symbol in both speaking and writing. While I wrote, Olga Sevostyanova would present the concept in movement—and vice versa. We wished to push forward the idea of working with subsets of the initial set of movements, and the result was challenging. We split the initial set of movements into several subsets and then intermixed them and added some supplementary connecting movements $[\beta_1, \beta_2, \beta_3]$; as a result, we created the sequence $[\gamma_0, \gamma_1, \gamma_2, \beta_1, \gamma_5, \gamma_6, \beta_2, \gamma_3, \gamma_4, \beta_3, \gamma_7, \gamma_8]$.

## Conclusion and Remarks

This project was about bringing formal mathematics into a dance performance. In the course of the performance, we presented mathematical concepts to the audience, delivering them in writing and speech, while illustrating the ideas with movement within the artwork. The use of mathematical terms and symbols in this dance work gestures towards the expectation that contemporary dance artists have to constantly generate new languages and approaches.

While set theory inspired and guided us initially, we eventually operated with sequences instead of sets. Thus, the notation used in this paper has been slightly altered compared to the notation expressed in the performance. Furthermore, the algorithms described above, which deal with sequences, might alternatively be displayed by a programming language; you can find their possible realisation in Python (the program itself and its output) in the online supplement to this paper.

## References


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